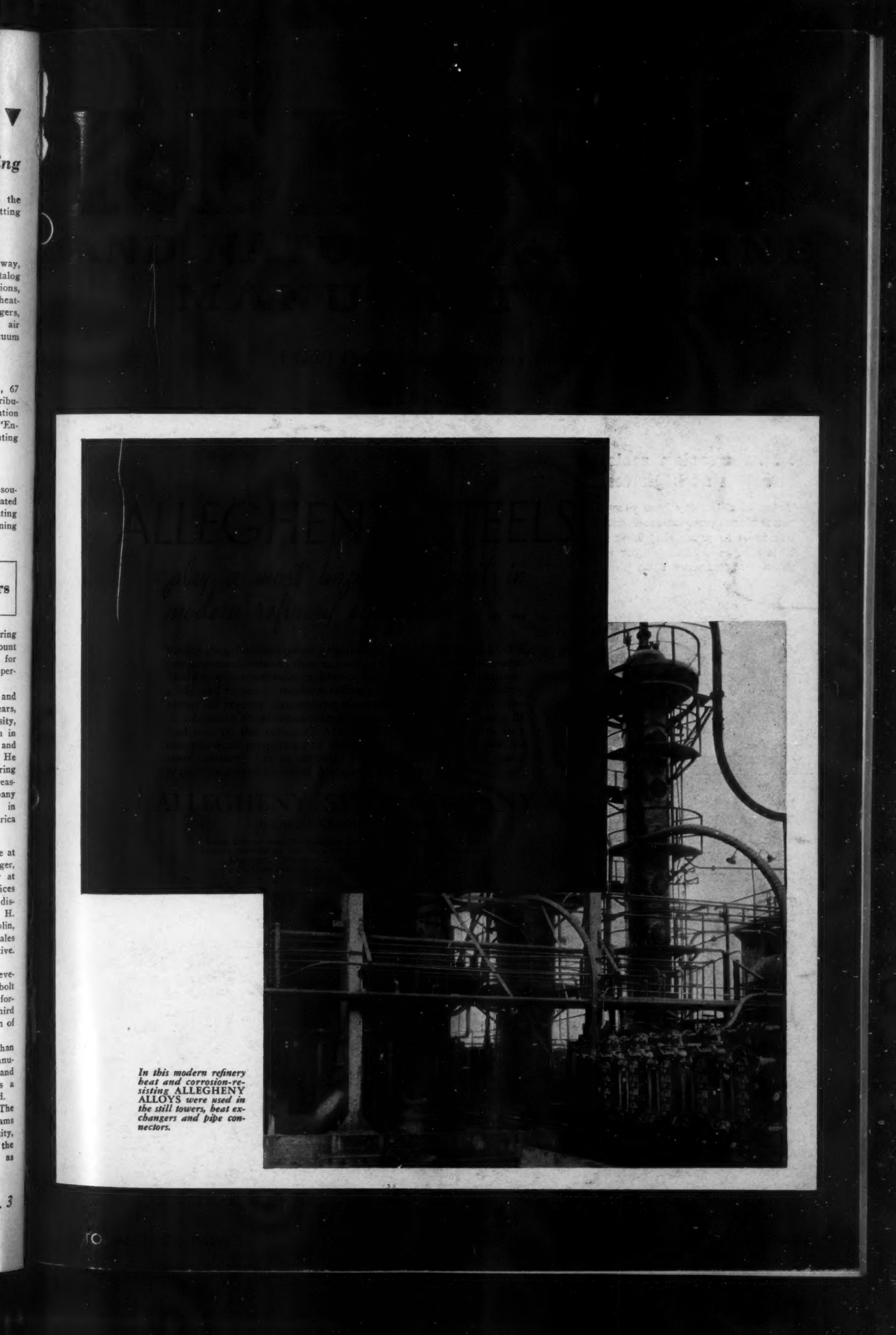

In this modern refinery heat and corrosion-resisting ALLEGHENY ALLOYS *were used in the still towers, heat exchangers and pipe connectors.*

STANDARD *seamless* STILL TUBES

1 4%-6% CHROMIUM

. . . Corrosion resistance and strength at high temperatures

Tubes of this alloy have proved at least four times more corrosion-resistant than plain carbon steel in processing high sulphur stocks. This alloy, also, has greater strength at elevated temperatures than plain carbon steel.

2 4%-6% CHROMIUM plus ½ of 1% Molybdenum or 1% Tungsten

Higher resistance to corrosion and embrittlement at working temperatures

These alloys have somewhat greater corrosion resistance than 4%–6% chromium steel . . . have considerably greater creep strength . . . are not brittle at operating temperatures or after cooling down from operating temperatures.

3 LOW CARBON MOLYBDENUM

Greater resistance to creep at elevated temperatures

This alloy affords an economical solution to the problem of obtaining tubes for operating conditions where corrosion resistance is not essential, but creep strength higher than that of carbon steel is required.

Our metallurgical and engineering department is thoroughly familiar with the service requirements of still tubes for cracking high sulphur, corrosive crudes at elevated temperatures and increased pressures. They will be glad to cooperate with you in determining the correct type for your particular service.

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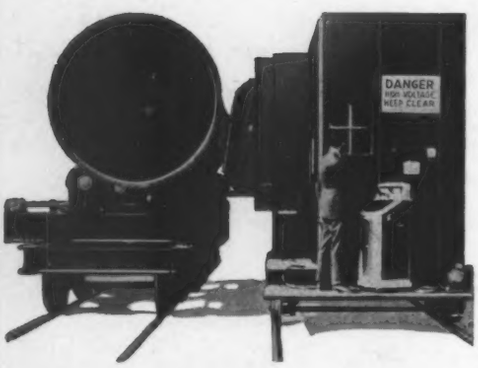

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VOLUME 12, No. 4 APRIL, 1933

Metallurgical Symposium

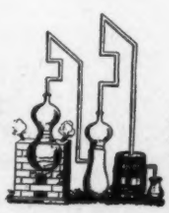
THIS month, and next month, THE REFINER devotes its pages to the presentation of a symposium on the metallurgy of petroleum refining equipment. To this work a number of leading metallurgists and technologists of both the oil refining and steel industries have contributed articles of real value. Primarily, the purpose of the symposium is to assist in clarifying problems of proper adaptation of the right metal, steel or alloy steel, to the various services in refining.

During the past four or five years refiners and manufacturers have done a vast amount of experimenting and development work in the application of various alloy steels. Unsatisfactory experience has been reported in certain instances. As usual with new materials of construction, a great deal of exchange of information and co-operation between refiners and manufacturers has been necessary to further the development of both materials and processes. As a result, the refining industry now has a considerable number of reliable alloys for use. Because of increased knowledge and care on the part of both user and manufacturer, some of the alloy steels are now out of the experimental class. Further information is required regarding the proper use or application of the various available materials. Much of such information is presented in the contributions to this symposium.

Because of the conditions of temperature, pressure, and corrosion in the refining industry the demand for alloy steels has been steadily increasing during recent years. The severity of service requirements is not equaled in any other industry. Engineers and metallurgists in both the refining and steel industries are to be complimented on the thoroughness of their co-operative study and the success attained in the solution of the many problems with which they have been confronted. Much yet remains to be done. New developments of importance are being announced periodically as the work progresses. Much new data is presented in the present symposium, new thoughts are advanced, processes discussed and experience records detailed.

Selection and applicability of many alloys and metals is discussed in the group of articles presented covering such important refining equipment as cracking still tubes, preheater and heat exchanger tubes, return headers or bends, condenser pipe, flanges, bolts, tube hangers, fractionating columns, pressure vessels, valves, pumps and pump parts, thermowells, bubble caps, fractionating trays, reaction chambers, transfer piping, and so on.

The discussions presented at this time are comprised of the thoughts and knowledge of the individual contributors, based on the authors' experience and available information. Nothing final is attempted. The field of metallurgy is progressing rapidly. The metallurgy of special alloys is now possibly in the middle stage of development. As the scientific information piles up, coming as it does from a large number of industries, much further progress in development will come through the "borrowing" process. A large part of this progress will be contributed by the petroleum refining industry.



Metallurgy of Refining Equipment

R. L. DUFF

Metallurgical Technologist, Standard Oil Development Company, Elizabeth, New Jersey

ONE of the most important features, if not the most important, in the construction of an up-to-the-minute oil refinery is the selection and specifying of the proper metal for each and every operation. The temperature limitations will range from 1800° F. down to 100° below zero, while pressure requirements may run from a vacuum up to possibly 5000 pounds per square inch.

Properties required for these conditions might easily be met if other factors such as corrosion, temperature scaling, thermal expansion, thermal conductivity, machineability and above all, stability under service conditions, were not to be considered. The corrosive agents encountered will comprise all the known mineral and many organic radicals.

As an aid in making the correct metal recommendations for specific services, especially under corrosive conditions, a selected list of metals is made, samples of them are obtained and these installed under working conditions. These various samples should have the same shape and area, (a convenient size is 6 x 3 x ¼ in.) which will permit a uniform comparison. Tests of this kind are always to be preferred over laboratory tests when as a rule the conditions are what might be called too favorable. Chemically pure reagents may be used and field conditions in general are only approximated. Even tests made under working conditions must be viewed only as indications of results to be secured in service.

Before applying a particular metal or alloy to general use in any service, it is always best to try it out under actual working conditions on a limited scale as theoretical deductions some times prove false. One example is the use of Muntz or Admiralty metal bolts in cast iron flanges in condenser construction where sea water, an excellent electrolyte, is used as the coolant and at times almost boils, which condition accelerates corrosion. The above mentioned bolts under these conditions have given over 15 years service without affecting either the cast iron flange, pipe or bolts, even though one of the metals is electro positive and the other electro negative, including perfect condition for electrolysis to take place.

In locations that call for not only a non-corrodible alloy, but also one that possesses great strength, stability and temperature scaling resistance, then other tests must be conducted.

Short time elevated temperature tests will give an indication of what might be expected as to strength, but this method of testing lacks one of the most important variables, namely, time. We therefore must turn to another form of testing that will give us authentic data that is comparable to the stresses obtained in equipment under service or working conditions. This method of testing comprises temperature, stress and time and is called "Determination of Limiting Creep Stress" and requires carefully made equipment, great patience and considerable time. A true and accurate "creep determination" will require six months to one year to run, but the stresses obtained can be relied upon for design purposes.

STABILITY

We now have to contend with another most important property—"stability." This characteristic can be obtained by the use of a standard impact machine such as the Charpy in conjunction with an electric furnace, equipped with temperature control.

The furnace is charged with standard Charpy impact test bars machined from selected alloys and kept at the maximum temperature to which the alloys will be subjected in service. A set of three bars of each alloy are broken at temperature by the impact machine after given periods of soaking such as 1000, 2000, 3000 hours, six months and one year. Another set of three bars of each alloy is taken out of the furnace at the same time, allowed to cool and broken at room temperature. The difference between the original impact value obtained before test and that obtained at room temperature after a given period at elevated temperature will indicate the stability of any particular alloy for that period.

Temperature scaling tendencies can be determined either by test pieces installed in a combustion chamber or by observation of equipment in service.

The machining of the various alloys requires a different technique than is called for on common steel. The cutting edge of the tool is dressed differently and the speed of the machine must be changed to get the desired results. Considerable experience is often required before satisfactory results can be obtained.

At present most all of the larger oil companies are purchasing materials and equipment according to very definite metal specifications. The following is an out-

"THERE is no 'cure-all' alloy that will meet the oil refinery's requirements, but the alloy should be as fool-proof as possible to withstand the severe service conditions and abuse which it will be called upon to resist," Mr. Duff states.

In an interesting and valuable discussion of the metallurgy of refining equipment, Mr. Duff discusses the selection and applicability of alloys and metals for such important refining equipment as cracking still tubes, preheater tubes, heat exchanger tubes, condenser pipe, return headers or bends, flanges, bolts, tube hangers, fractionating columns, pressure vessels, valves, pumps and pump parts, thermowells, bubble caps and fractionating trays.

Mr. Duff's work in metallurgy is too well known to require further introduction here. The accompanying discussion will prove of value to have clipped and handy for ready reference.

METALLURGICAL SYMPOSIUM

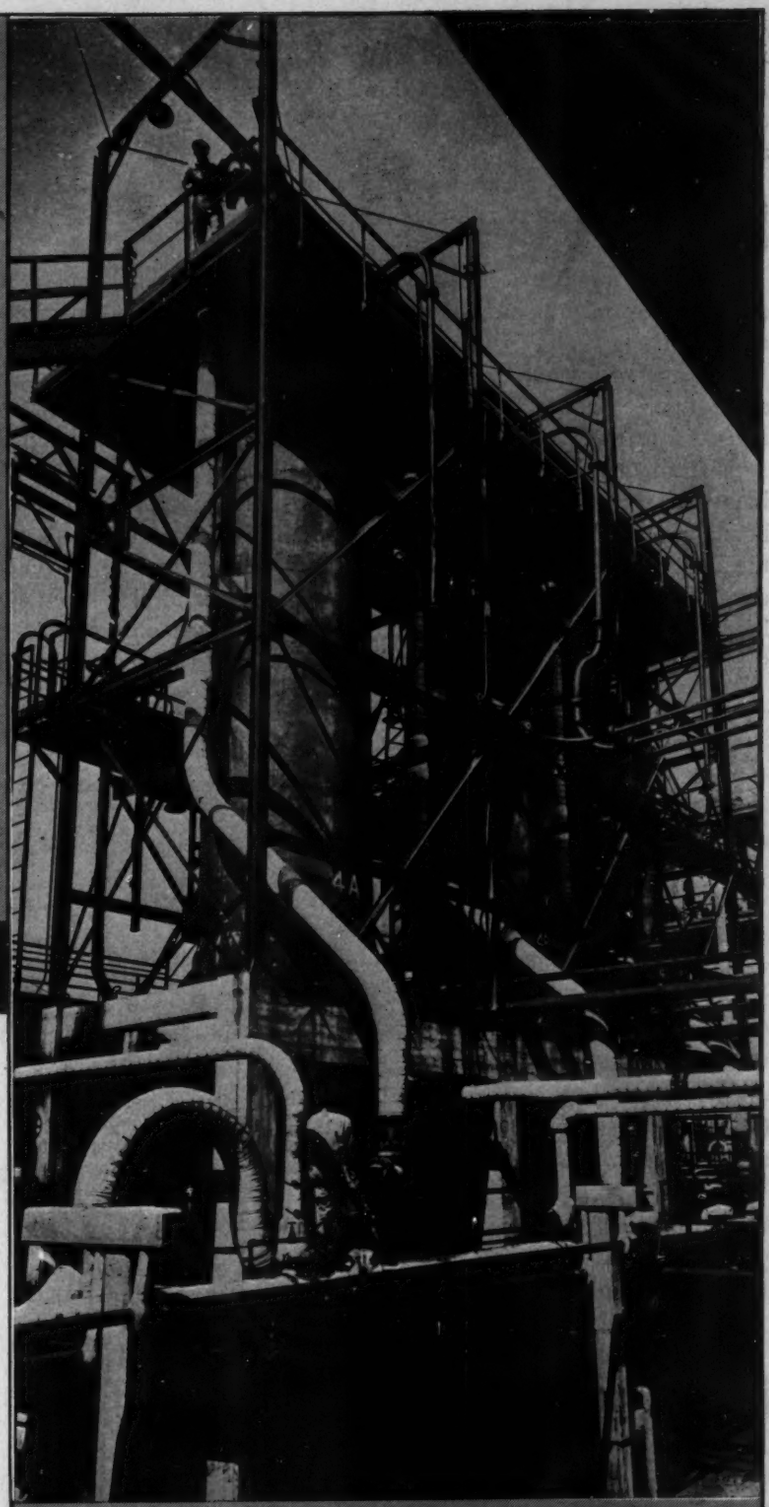
line of the specification for one of the most important alloys, i.e., 18 per cent chromium and 8 per cent nickel, which is widely used in fabrication of tubes for cracking unit, condenser and heat exchanger service. It covers the manufacture, heat treatment and inspection of tubular goods for use under severe service conditions where the temperature exceeds 750° F.

The billets from which the tubes are rolled must be furnished by an experienced and approved concern, the steel to be made by the electric furnace process, etc.

The chemical analysis is specified. Also, mill inspection of the ingots, blooms and rounds is given. This includes the etching of a disc cut from the top of each round representing the top of an ingot.

The method of manufacture of the tubes is given, i.e., either hot finished or cold drawn. If hot finished, they shall not be rolled below a temperature of 1700° F. Cold sizing of hot finished tubes is permissible.

If the tubes are finished at a temperature



Portion of one of the cracking unit installations at Bayway refinery of Standard Oil Company of New Jersey.

in excess of 1850° F. but below 2000° F., they shall be immediately quenched in cold water.

If the tubes are finished below 1850° F., or cold sized, they shall be heated to between 1850 and 2000° F. and immediately quenched in cold water.

All tubes shall be pickled, before being submitted for inspection; this removes all outside scale—a very necessary step.

The heat number is stamped on each tube and in addition a serial number, starting from one and up for each heat.

Two test rings are cut from each end of each tube and properly stamped. One ring is etched and the other is used for an expansion test. The etched ring must be free from any indication of sponginess, segregations, inclusions or mechanical defects, the metal must be homogeneous, both throughout the circumference and the depth of the tube wall. The expanded ring must expand a certain percentage over a tapered mandrel having a slope of 1 to 10. Calculations are based on the inside diameter and the required percentage varies with the ratio of the wall thickness of the tube to its diameter. Other tests such as expanding and flaring, flattening, hardness, crushing and tension tests are required. Also a hydrostatic test on each tube, the pressure applied being determined by a specific formula. In addition, certain tolerances are specified as to diameter, wall thickness and length, and the finished tubes shall be free from scales, pits, slivers, seams, distortion and other defects, shall have smooth ends free from burrs and shall have a workmanlike finish.

A wide variety of metals and alloys are utilized in the construction of a refinery. Cracking unit tubes in the hottest or radiant section of the furnace require low carbon, 18 per cent chromium, 8 per cent nickel tubes, and in the convection section both plain carbon and 4/6 per cent chromium plus .4-.6 per cent molybdenum tubes are used.

Preheater tubes—here the stock run and the temperature determine whether the tubes are to be plain carbon or 4/6 per cent chromium with molybdenum.

Heat exchanger tubes—stock run, temperature and pressure decide the material here, which can be a good grade of brass, such as Admiralty metal, 4/6 per cent chromium plus molybdenum, or 18 per cent chromium, 8 per cent nickel. Tube sheets and headers should be of the same material as the tubes, or serious pitting will result.

Condenser pipe—the proper metal to reccommend depends upon the coolant used, temperature and pressure of the vapors. Extra heavy steel pipe is usually used; also, ordinary cast iron or alloy cast iron. The best proposition is to utilize old discarded 18 per cent chromium, 8 per cent nickel tubes, if available, especially in the upper rows of condenser pipe where accelerated corrosion occurs.

Return headers or bends are usually made from carbon steel, low chromium-nickel of 4/6 per cent chromium plus molybdenum. In some instances where serious corrosion occurs, the plain steel header boxes are lined with cement which protects the metal.

Flanges for piping are usually made from common steel, or a low chromium - vanadium steel.

For bolts for temperatures below 500° F. and less than

Inside the stall at the Hydrogenation Plant, Standard Oil Company of New Jersey, Bayway plant. Forty foot alloy steel towers with seven inch walls, operating at 3600 pounds pressure and 750 and 1000 deg. F.

General view of central battery of cracking coils at Standard Oil Company of New Jersey, Bayway refinery.

300 pounds pressure, common steel is used, and for services below 1000° F. and above 300 pounds pressure, a material quite similar to A.S.T.M. Specification A-96, Class "C" is used. Chrome nickel, chrome vanadium, chrome manganese or other alloy steels may be used.

It is stipulated in the specification that the manufacturers desiring to receive inquiries for bolt material must first submit samples of their material for approval. Complete information concerning chemical analysis, physical properties and method of heat treatment, if any, should accompany the samples. In locations where serious corrosion occurs an alloy of the following approximate composition is used: Carbon—.45 per cent, Silicon—1.25 per cent, Chromium—8.00 per cent, Nickel —20.00 per cent.

Studs, bolts, etc., that derive their higher physicals from special heat treatment should be used with caution at temperatures above 750° F., due to the fact that time is one of the most important factors or variables in the use of metals at elevated temperatures, i.e., if used in the neighborhood of 750 or 800° F. over a long period, such as 8000 hours. They will arrive at the same condition if kept at 1200 or 1300° F. for a much shorter period. Therefore, a bolt that might have an initial strength, due to the heat treatment, of 125,000 pounds per square inch, if kept at 800° F. for a year or more will be found to have a strength of only 90,000 or 100,000 pounds per square inch at the end of that period.

Tube hangers and supports are made from high chromium nickel alloy having marked resistance to scaling.

Fractionating columns or bubble tower shells are constructed from common steel.

Pressure vessels—the material for their construction will depend on temperature conditions, the type and size of vessel and whether it is riveted, forged or welded.

Valves and trim—this covers a large field and the construction depends entirely upon the service required of them.

Some of the low pressure cast iron or semi-steel bodies have the rings as an integral part of the body fitted with steel stems and others have cast iron bodies, bronze trim. Then there are the cast steel drilling valves for 1500, 2500 and 3000 pounds test pressures with a body of cast steel having a tensile strength of over 70,000 pounds per square inch, yoke bushing of bronze, stem of high grade steel having a minimum tensile strength of 125,000 pounds per square inch, and bolt studs from A.S.T.M. Specification A-96-25T, Class "C" material.

For valves for 900 pounds and 900° F. or 1100 pounds and 600° F. service, the bodies and bonnets should be circular type. Proper provision should be made in the body design to take care of expansion and contraction strains on the seat rings (which are screwed in), to prevent distortion or loosening under temperature. The body should be cast chrome nickel steel and the trim of stainless steel having the following chemical requirements: Carbon—0.12 per cent maximum, Chromium—11.5 per cent—13.0 per cent maximum. Other trim sometimes used is 18 per cent chromium, 8 per cent nickel, or 20 per cent nicked, 8 per cent chromium, etc.

Pumps and pump parts are almost as numerous as the valves and depending upon the service will require similar alloys as are used in valve construction.

Thermowells made from 20 per cent nicked, 8 per

cent chromium and approximately .15 carbon give very good satisfaction.

Bubble caps not only from a service standpoint, but from an economical standpoint, are made from cast iron.

Fractionating trays as a rule, are made from cast iron, although some are constructed from steel.

Proper metals will be recommended for certain specific operations as to temperature and pressure conditions and will be giving entire satisfaction until the design engineer or some other expert makes certain efficient or economic changes in either the operation or design which seriously alters the original conditions. Possibly the alloy tubes have been retained without changing the diameter or wall thickness; they were entirely safe in the first instance but with the new conditions they were too close to the calculated temperature and pressure limits so that a slight deposit of coke or localized heating would raise the metal temperature above the calculated safety limit with the result that the tube failed.

There is no "cure all" alloy that will meet the oil refinery's requirements, but the alloy should be as foolproof as possible to withstand the severe service conditions and abuse which it will be called upon to resist.

In regard to the expensive 18 per cent chromium, 8 per cent nickel tubes which have the heat and serial numbers tamped upon them, a careful record is kept of the location of each tube in the cracking unit setting and if by chance one fails, its complete history is easily obtained. The carbon content of this alloy, particularly for high temperature service, should not exceed 0.07 per cent. Carbides will gradually migrate to the crystal boundaries under service conditions such as 1200 ° F. or at low temperatures in the neighborhood of 900° F. over a period of say several thousand hours. It is at the grain boundaries that corrosion or disintegration takes place. Therefore, the common sense thing to do is to specify a low carbon content in all chrome and chrome-nickel alloys. The low carbon content will also have a tendency to prevent air hardening in the straight chrome steels.

Most straight chromium alloy steels are air hardening, regardless of any special heat treatment and will at metal temperatures above 900° F. over long periods, become quite brittle at atmospheric temperature. Tubes in this condition could very easily be fractured during the cleaning operation.

As the percentage of chromium is increased just so is the alloy's resistance to corrosion increased. The alloy containing 12-14 per cent chromium is one of the most important of the series due to its corrosion and abrasion resistance, which is obtained by special heat treatment. Polishing improves its corrosion resistance.

One of the most important low contented alloys is the 4/6 per cent chromium steel. If this alloy is to be used safely and without risk, it should have an addition of 0.4-0.6 per cent molybdenum, or 1.0 per cent tungsten added. These additions apparently stabilize the alloy and in addition make it more corrosion resistant.

Tungsten is an imported metal, limited in quantity and much more expensive than molybdenum, which occurs in large deposits in Colorado. If tungsten were used in large amounts, the price would soon be prohibitive. On the other hand, only half the percentage of molybdenum is required to get the same results as with tungsten.

Four to six per cent chromium tubes scale due to temperature to the same extent as do carbon steel. They have greater strength and are more corrosion resistant than carbon steel at high temperatures, but are not in the same class as the 18 per cent chromium, eight per cent nickel alloy and should only replace carbon steel.

The 18 per cent chromium, eight per cent nickel type presents a basic structure of alloys that is entirely different from that of the straight chromium alloys and consequently the properties of these austenitic steels vary greatly from those steels of the ferritic type.

The chrome-nickel steels possess great toughness and are non-magnetic and ductile. None of these alloys can be hardened by heat treatment but they are readily hardened by cold working.

Austenitic alloys show greater strength at high temperatures that the ferritic steels and in general, as the chromium and nickel are increased (up to 30 per cent) the strength, resistance to corrosion and resistance to oxidation increase likewise.

Regardless of the printed statements by the producers that these chrome alloys can be safely gas welded and brazed, this procedure is not safe, especially if the welded material is to be used under temperature and pressure or corrosive conditions. Chromium or any of its alloys have a great affinity for carbon, so that when acetylene gas is used it is almost impossible to have continuous perfect combustion conditions. Therefore, the weld will contain variable amounts of carbon, which condition in turn decreases the alloy's corrosion resistance.

Brazing takes the life out of these austenitic steels due to the fact that the copper penetrates all the grain boundaries, ruining the metal's ductility.

Even though electric welding is practiced, the consumer has his difficulties when welding these alloys, especially when they have a low carbon content, i.e., below .07 per cent. Welding rods of the same chemical analysis as the material to be welded, should be used.

Some of the coated wires on the market for low carbon alloy welding contain over two per cent free carbon in the coating. Another coated rod gives good results but the welding operation has tendency to "undercut," due to the higher fusibility of the coating on the wire than the wire itself.

In one sense the alloy producers have the easiest part of the alloy game. Very few of them have first hand information as to the data that is printed in their catalogs and pamphlets, and woe be unto the consumer that accepts in good faith all that he reads. Many of the producers have "pet" alloys that absolutely do not live up to their advertised qualifications.

PART I

Meeting Some of the Problems of the Pressure Vessel User

T. McL. JASPER, O. E. ANDRUS, L. J. LARSON

Research and Development Engineers, A. O. Smith Corporation.

THE history of pressure vessel development can be characterized by a series of increasing demands by the pressure vessel user which have been met by the pressure vessel manufacturer.

The invention of the steam engine marks the starting point in the demand for pressure equipment on a quantity basis. This demand started on a relatively small scale when measured by present day standards, and has expanded into the use of large quantities of steel and other materials. Many different methods of fabrication have been used for producing pressure vessels, and most of them are still in use. Cast iron, bolted and riveted wrought materials, forge welded cylinders, solid forgings, and most recently, autogenous welded vessels have marked the general history of the development.

METALLURGICAL SYMPOSIUM

THE oil and chemical industries have made the most severe demands on pressure vessel equipment in recent years and this has called for the latest development in welding. This method of construction has made is possible to build pressure vessels of various materials to any shape, size, or thickness, and for the first time the vessel could more completely adapt itself to the processes of industry and thereby lend itself to the greatest economies in production. These industries have been able to make the greatest economical use of vessels of large size for application with high pressures and temperatures which could only be economically fabricated by the use of arc welding.

Today, autogenous welding is in favor as the most appropriate method of vessel construction for the most severe service. It is also gradually replacing the older methods of vessel construction for ordinary pressure vessels. Single vessels weighing as much as 700,000 pounds have been built by welding to operate at temperatures between 900°F. and 1000°F. Such welded vessels have been in satisfactory operation over four years and other similar vessels, but of less weight, have been in successful service for over seven years. Other vessels of welded alloy steel have been in successful operation at a pressure of 5000 pounds per square inch, coupled with relatively lower temperatures. The size and weight of such equipment is limited primarily by transportation facilities.

Welding has had a dominating effect in the improvement of design of vessels in that overlapping of metal is unnecessary, and this is associated with decided gains in the useful value of joints. Until autogenous welding had been perfected to produce strength and ductility comparable with that of the steel joined, the design of efficient heads and reinforcing of openings was of little importance since the joint was the weakest part of the structure.

The application of improved joints and shapes made possible by welding required that all openings be reinforced to bring up the strength of the finished structure in a balanced manner. The proper application of reinforcement can be more ideally made by welding than by any other commercial means.

With the possibility of improved joints, the successful forming of thick metal and the ability to apply improved designs the user has been enabled to choose a vessel to suit his process rather than to modify his process to suit the limitation of vessel construction. This results in much greater economy of operation and reduced equipment cost per unit of production.

Associated with welding, tests of large size vessels to destruction, constructed in various ways, have discovered what factors of safety were really available in vessels which had been in general use by industry.

It may be said that rarely have vessels had real factors of safety which exceeded three, although they have been figured to have values of from four to five, or even greater. It is possible, therefore, for the user of vessels by proper design of arc welded construction to take advantage of this fact to reduce the

weight of his equipment for the real factors of safety established as satisfactory by use or to increase his operating safety without increasing the weight of his vessels.

The economic use of materials by the application of balanced design which apply the real factors of safety that have been established by use is well exemplified by the development of the airplane. Had the attitude of the engineer not been directed toward this phase of the problem, there would have been very little possibility even today in the safe commercial use of the airplane for transportation purposes.

The authors would respectfully suggest that the user of equipment, who is, as it were, in the firing line of service, should take a most active interest in shaping the standards under which vessels should be built and operated in order to obtain the advantages possible by balanced design.

New economic materials for vessel construction are being demanded to meet the special conditions of industry. Much work has been accomplished in the production of such materials and the fabrication of them into vessels. The general requirement for an economic material is that with due regard to safety, resistance to high or low temperatures and varying corrosion conditions, the resulting equipment shall cost the least per unit of production for a given quality of product. This does not mean that the least costly metal per pound is the most economic material.

PROBLEMS OF THE PRESSURE VESSEL USER

With respect to the pressure vessel itself, the problems confronting the user depend upon the service for which the vessel is used.

In the oil industry, pressures may range from atmospheric to 3000 pounds per square inch, the temperature may be from atmospheric to 1000°F., which shows a dull red to the eye. The corrosion may be negligible, or it may be as much as one inch of the plate thickness per year on an unprotected vessel. As a rule, the temperatures of oil refinery operation vary from 800°F. to 1000°F., and this is sufficient to materially reduce the long time ultimate strength of the steel.

Since the cycle of oil refining is relatively short, it becomes desirable to heat and cool the vessel rapidly so that the off stream period of the vessel is reduced to a minimum. Due to the extreme inflammability of the oil at the high temperature of operation, leaks are prohibitive. Economy of operation requires vessels of large size and suitable shape. The demands on the refiner to handle oil stocks of all possible kinds so as to take advantage of market conditions, requires great flexibility in equipment.

The steam industry is beginning to appreciate the economies of higher pressures and temperatures. In this industry, the problem is primarily one of resistance to pressure. With increasing pressures, an increase in temperature prevails. The type of corrosion generally encountered in steam vessels is caused by caustic embrittlement. Caustic embrittlement is only found in the presence of stress concentration such as occurs in riveted joints. Such areas of high stress are eliminated in a properly designed welded vessel.

The pulp and paper industry needs a vessel to more economically resist high corrosion. The pressures and temperatures are relatively low. The miscellaneous chemical industry, in addition to one or more of the requirements enumerated above, sometimes has to meet the problems of freedom from staining and contamination. The requirements of operation frequently demand complex designs which call for a most flexible method of construction.

ECONOMIC MATERIALS

The load carrying steels most appropriate for pressure vessel fabrication are those which can be satisfactorily cast into ingots suitable for rolling into large plates. The steels which fall into this class can be successfully welded by the electric arc. The steels which are used to resist corrosion need not be cast into large ingots. These steels can be welded to produce a corrosion resistance in the weld equal to that of the plate, and can also be bonded to the load carrying plates by spotwelding or other suitable methods.

The load carrying steels include carbon and minor alloy steels. The carbon steels are, in general, the least expensive. Where light weight, relatively thin sections, or resistance to certain fluids is required, the low alloy steels may be economically permissible because of their relatively high strength or improved resistance to corrosion or deterioration.

The highly corrosion resistant steels are economically necessary in certain processes because no suitable substitute has been discovered. These steels are very expensive, and are limited in application as load carrying materials. Where the operating conditions permit the use of a thin wall, the entire vessel may be made of these more costly materials. The majority of vessels subjected to corrosion, however, require considerable thickness, and, therefore, make it more economical to use carbon steel for load carrying purposes and a spot welded alloy liner as a protection against corrosion.

PHYSICAL PROPERTIES

The knowledge of the physical properties of the above steels at ordinary and at elevated temperatures is essential if reliable designs are to be made from them to operate under various conditions of service. It is not the purpose of this discussion to produce a mass of data on the various steels because so much of this information is already available. Especially is this true of strength values at ordinary temperatures. It will be the purpose, however, to outline the method of producing and applying reliable elevated temperature values by taking one type of steel at a definite temperature and outlining

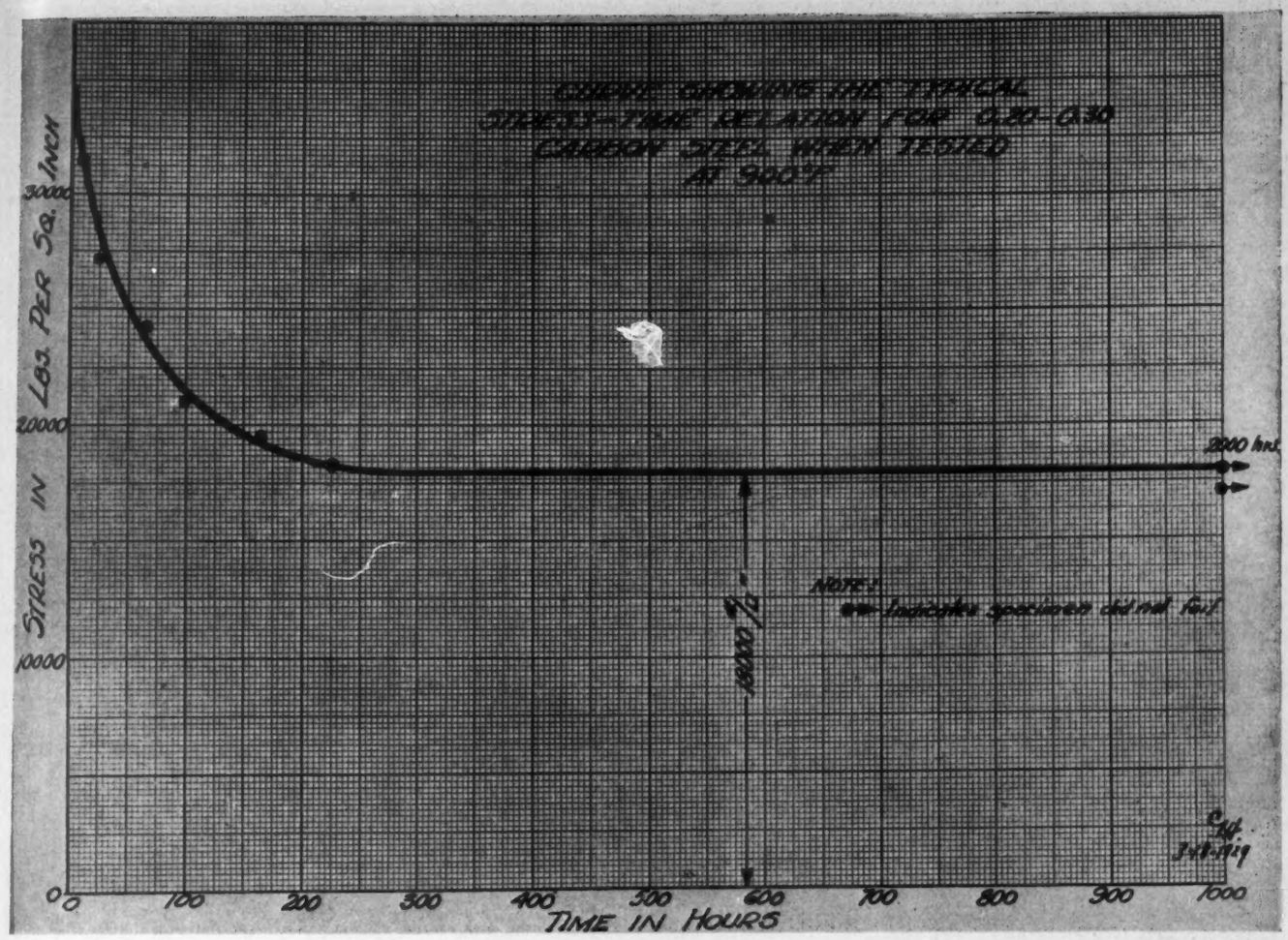


FIGURE 1

the method of testing and assembling the data for use in vessel designs.

Figure 1 shows the test data for a .20-.30 per cent plain carbon steel and represents the long time ultimate strength at 900° F. It indicates on the Y ordinate that at this temperature the short time ultimate strength is about 35,000 pounds per square inch, while the long time ultimate strength is 18,000 pounds per square inch. The method of testing has been to make several specimens of this steel and load them separately to a given stress until failure occurs. The time and stress for each specimen is then plotted and the resulting curve drawn. In this manner, the value of the curve in terms of stress, which curve is parallel or very nearly so to the X axis, represents the stress that the steel can carry for an indefinitely long period at this temperature.

Figure 2 shows the test data which was obtained on the same steel but this time it repreesnts the long time elastic limit or what is believed to be the long time yield point of the steel at 900°F. This method of test was invented by one of the authors in 1928, and the curve shown is of the first test data taken. Eact stress-strain curve represents a different rate of loading the test specimens. The value of the elastic limit or yield point for each rate of loading is plotted along the time axis and represents the time during which each increment of load was allowed to exert itself upon the specimen before another increment of load was added. The elastic limit values so obtained are represented as ordinates. In this manner, by correcting the elastic limit values a curve approaching a constant stress value is obtained, which has been called the long time elastic limit. For the .20-.30 per cent carbon steel, the short time elastic limit is about 18,000 pounds per square inch, and the long time value is 11,700 pounds per square inch.

This method is suited for testing steels for elastic strength at temperatures for which long and short time elastic values are different. It has been adopted in preference to the creep method of testing, which is often unreliable because results are affected so greatly by small amounts of oxidation and requires exceedingly accurate and sensitive measuring instruments which must be operated in the absence of vibration and small temperature changes. The time and care necessary for obtaining easily reproducible results by the method outlined here is only a fraction of that required in obtaining reliable results by the creep method of testing.

Figure 3 shows a typical curve for suggested allowable working stresses at different temperatures for the steel used in tests as shown in Figures 1 and 2. It has been built up on the basis that an allowable

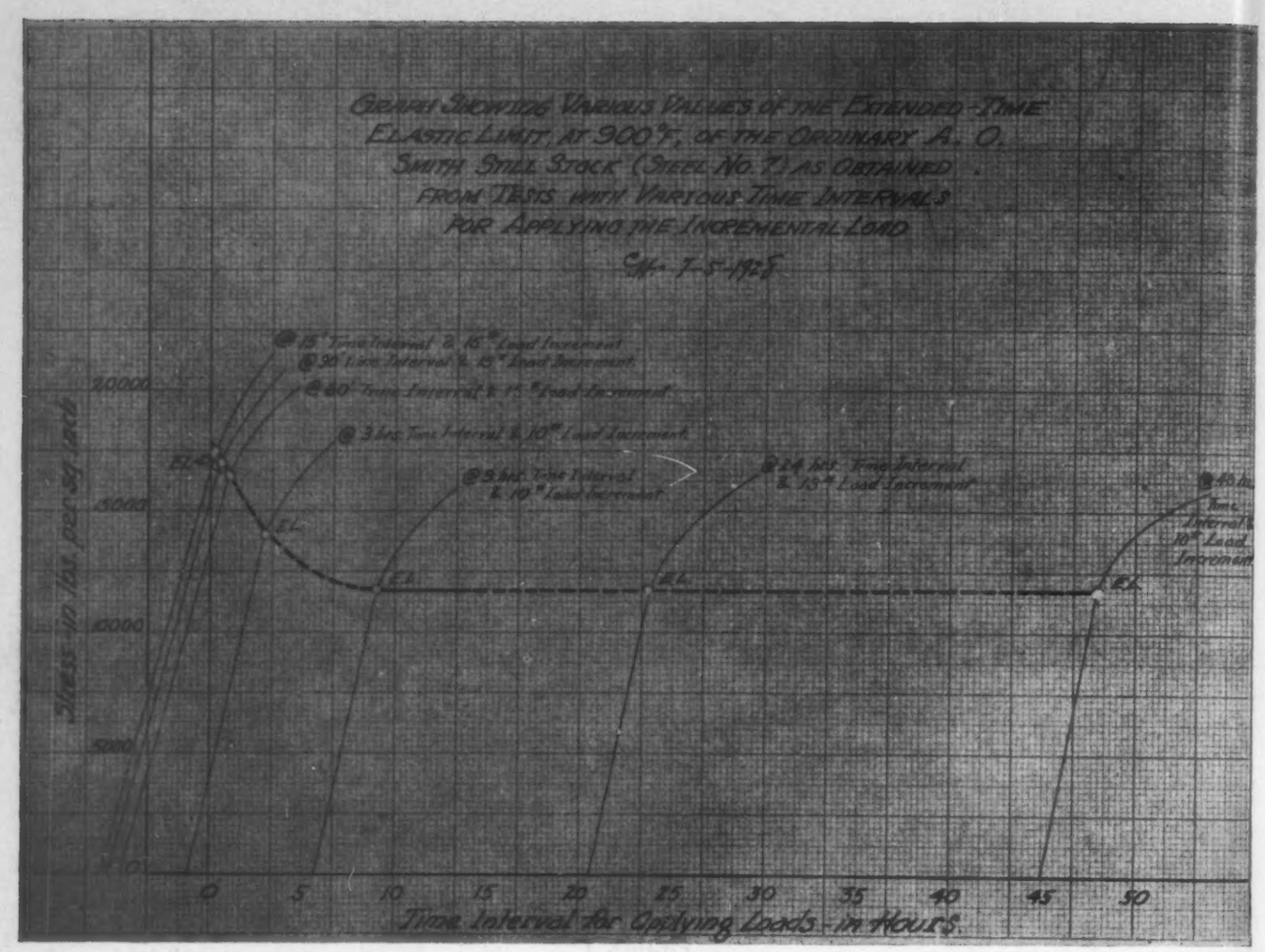


FIGURE 2

working stress of 6000 pounds per square inch or a factor of safety of three based on the long time strength at 900°F., is sufficient for the most hazardous service. For sudden impulses of load, this safety factor, however, is more nearly six. At atmospheric temperature, the allowable stress shown by the curve represents a factor of safety of about 4½. This curve was prepared several years ago, and before the major improvements in vessel design had been applied. With the improvement in design the values may be safely increased at the lower temperatures. This curve is included as an example of how test results shown in Figure 1 and 2 can be applied by the designing engineer.

The question of proper designs enters into the consideration of appropriate factors of safety to allow for pressure vessels. This will be considered under the heading of vessel design.

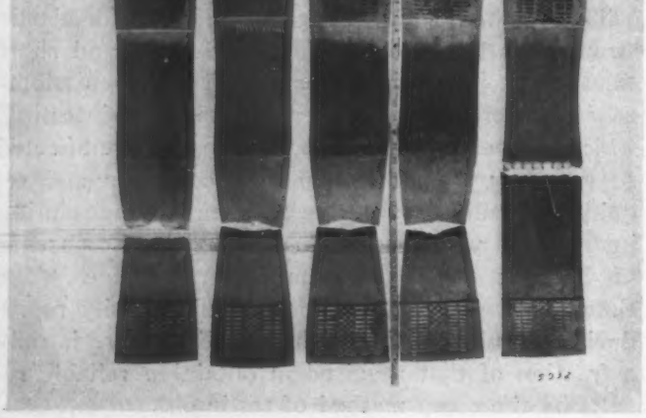


FIGURE 4

Tensile test on specimen cut across a weld joining plates six inches thick. The area through the weld was reduced various amounts by drilling holes. Each hole is .2 inches in diameter.

CORROSION RESISTANT PROPERTIES OF STEELS

Corrosion has long been the cause of worry on the part of the pressure vessel users. Realization of the economic value of some type of protection against corrosion is now general. Companies have suffered casualties and serious property damage in consequence of corrosion. The danger to personnel and the cost of replacement and repair have been erratic and have given rise to perplexing problems. Shutdowns have entailed great overhead expenses and appreciable loss of production profits. Thinning of the walls of vessels has necessitated pressure and temperature drops which have decreased yields, throughputs, and the flexibility of operation. Losses from

high insurance rates and low personnel efficiencies have resulted from disastrous explosions, fires, and leaks.

The chemical tests to establish the resistance to corrosion of different steels which might be used in the fabrication of pressure vessels could start in the laboratory. Such laboratory tests were made to simulate the temperature, pressure, and fluid conditions which were found in the commercial processes for which it was desired to build vessels. These tests enabled quick determination of the probable behavior of many materials when placed under service conditions. Such tests involved plates, welds, fabrication methods, and heat treatments.

The methods of pressure vessel fabrication were studied to discover if various adopted processes could be improved upon, with the result that the best processes of fabrication have been adopted for pressure vessel manufacture. For the oil industry, the carbon and low alloy steels in general were found to be equally attacked by the corrosive oil refinery fluids while the high chrome and chrome-nickel alloys were found to suffer only a negligible corrosion loss.

The second step was the verification of the laboratory results on a semi-commercial scale by subjecting test samples of the most promising materials to refinery conditions of temperature, pressure, and types

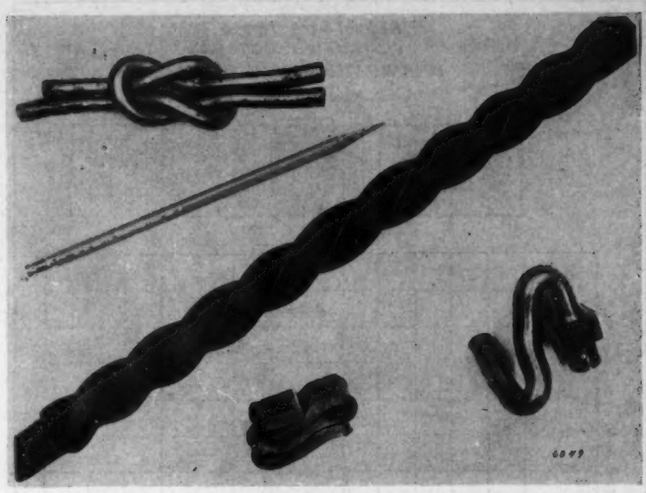


FIGURE 6

Specimens cut entirely from deposited weld metal showing the typical ductility of the Smithweld.

of extremely corrosive oils. These tests were further used as a guide to select materials, welding methods, fabricating methods, and heat treatments for the application of liners in refinery and other equipment subject to corrosion.

The final service tests on refinery equipment have verified the findings of the laboratory and semi-commercial tests and show no apparent attack on the

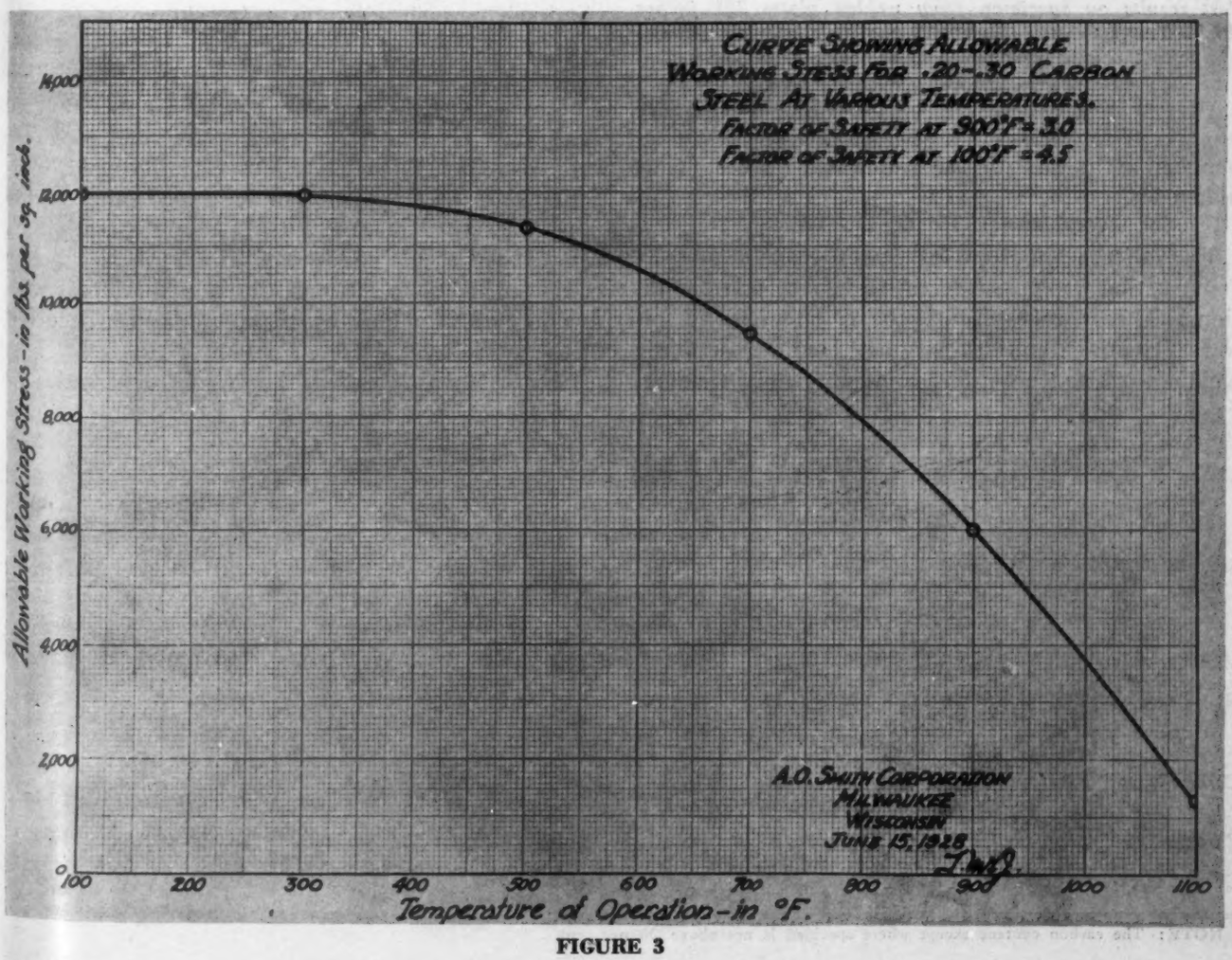


FIGURE 3

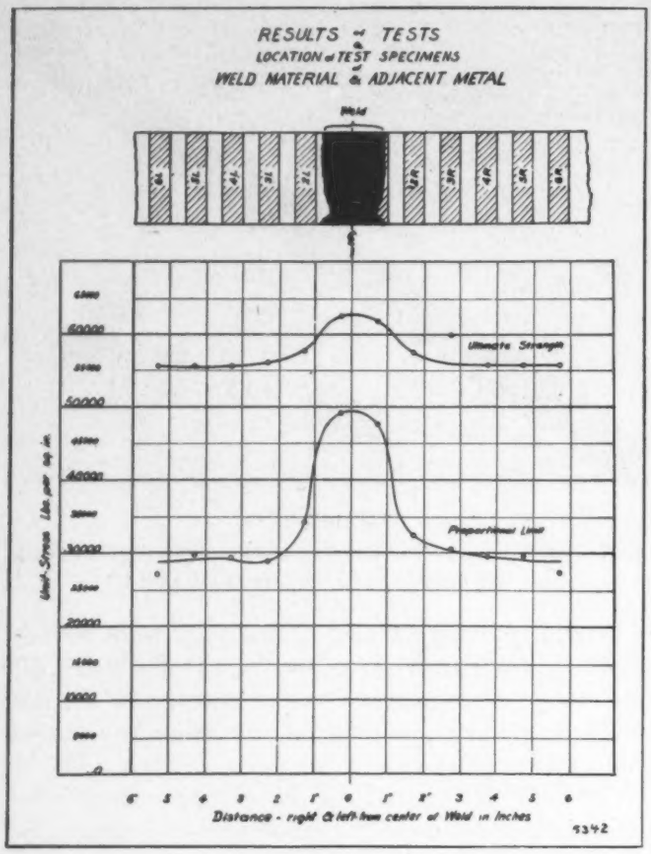


FIGURE 5

Test results on specimen from welded plates 2⅝ inches thick. Test specimen was cut at one inch intervals parallel to the weld and pulled in the same direction.

corrosion resistant liners after from five or six years of service. Work has been carried forward in a manner similar to this for the paper and miscellaneous industries.

WELDABILITY OF METALS

Each of the important processes available for the construction of pressure vessels has certain limitations. These processes may be enumerated as follows: riveting, bolting, forging, hammer or forge welding, resistance welding, and autogenous welding.

Of the various types of autogenous weldings, the metallic arc process utilizing a properly coated electrode is the most flexible in application to produce a reliable joint. It was only with the development of such electrodes, associated with proper methods of application, that welding became an established method of construction for pressure vessels of large size and thickness. This process has been satisfactorily applied to carbon and alloy steels and to various other metals and alloys.

The carbon steels, which are the basic materials used for pressure vessel construction, can be welded in thickness as great as has yet been required. Sections composed of single plates as thick as 5½ inches and of multiple plates much greater in total thickness have been satisfactorily welded into pressure vessels. Such sections as shafting up to 14 inches in diameter have also been welded and are in successful commercial use.

It is the commercial practice to adjust the physical and chemical properties of the deposited weld metal to suit the type and strength of the steel being welded. In this manner, these properties are adjusted so as to produce a strength greater than that of the plate, a ductility only slightly less and a resistance to service corrosion superior to that of the plate.

Representative results on the physical properties obtained by such adjustment are shown in Figures 4, 5, and 6. Figure 4 shows a group of tested specimens which were taken transversely to the weld in a plate of six-inch thickness. It will be noted that all of the failures which occurred in the steel plate are about six inches from the center of the weld, indicating that the plate material adjacent to the weld is not reduced in strength by the welding operation. It can also be seen that the weld strength is superior to that of the plate, since in all of the specimens with five or less two tenths-inch holes, failure occurred in the stock.

Figure 5 which shows the results of a series of

TABLE I

Showing Typical Physical Properties in Plate and Weld Metal for Steels Suitable for Vessel Construction.

KIND OF STEEL		STEEL PROPERTIES			WELD PROPERTIES		
		Yield Point lb./sq., in.	Ultimate Strength lb./sq. in.	Elongation % in 2"	Yield Point lb./sq. in.	Ultimate Strength lb./sq. in.	Elongation % in 2"
Carbon Steel	C Max. .20	25,000-35,000	45,000- 55,000	40-50	40,000-45,000	50,000- 60,000	35-45
	C .20-.30	30,000-40,000	60,000- 70,000	30-40	45,000-50,000	60,000- 70,000	25-35
Manganese Steel	Mn 1.0-1.5	40,000-60,000	60,000- 90,000	25-35	50,000-75,000	65,000- 95,000	15-30
Nickel Steels	Ni 1.0-2.0	40,000-50,000	60,000- 70,000	40-50	45,000-55,000	60,000- 75,000	25-35
	Ni 2.0-3.0	45,000-60,000	70,000- 80,000	30-40	50,000-65,000	70,000- 85,000	20-30
	Ni 3.0-3.8	45,000-60,000	80,000-100,000	25-35	65,000-80,000	85,000-100,000	15-20
Chrome-Vanadium	Cr .80-1.10, V .15-.20	55,000-65,000	85,000- 95,000	25-35	65,000-80,000	85,000-100,000	15-25
Chrome	Cr 16.-20.	40,000-55,000	70,000- 85,000	20-40	55,000-65,000	75,000- 90,000	15-25
Chrome Nickel	Cr 17-20, Ni 7-10	30,000-45,000	80,000- 95,000	45-65	35,000-50,000	70,000- 90,000	20-45

NOTE: The carbon content except where specified is not above .30 per cent.

specimens taken in or parallel to the weld indicates that the strength of the stock adjacent to the weld is improved by the welding operation. This explains why the fractures shown in Figure 4 occurred at some distance from the weld. Bursting tests on full size vessels have also demonstrated that failures occur at some distance from the welded joints.

Figure 6 shows the ductility of carbon steel weld metal and indicates the severe punishment it will stand without failure. Although the weld in a pressure vessel will not be subjected to such abuse, the high ductility of the weld metal is the best insurance against the effect of suddenly applied overloads.

Metallurgical examinations of welded specimens of carbon steel of the type under discussion show that the deposited weld metal is cleaner and of a finer grain structure than the plate material. This is shown in Figure 7. The cleanliness and fine grain structure of the welds are undoubtedly associated with the fact that the weld metal corrodes less rapidly, causing welds in service to stand out in relief.

Figures 4 to 7 represent test results on .20-.30 per cent carbon steel having a minimum tensile strength of 55,000 pounds per square inch, and are made on specimens in the welded condition.

The welds for low alloy steels of the types sometimes used for pressure vessel construction behave in a manner similar to that shown above for carbon steel welds. In the case of these steels also, the commercial weld is equal in strength and has a ductility approaching that of the plate material.

Because of cost, the stainless metals which are used for vessel construction are limited to thin sections and to applications where staining, contamination or corrosion is important. Solid alloy vessels are limited to low pressure service conditions. For high pressure service it is necessary to protect the load bearing steels with a liner of stainless metal. The most appropriate method for attaching such liners is by electric spot-welding. For the oil and several other industries stainless steel of chrome and chrome-nickel have had wide application.

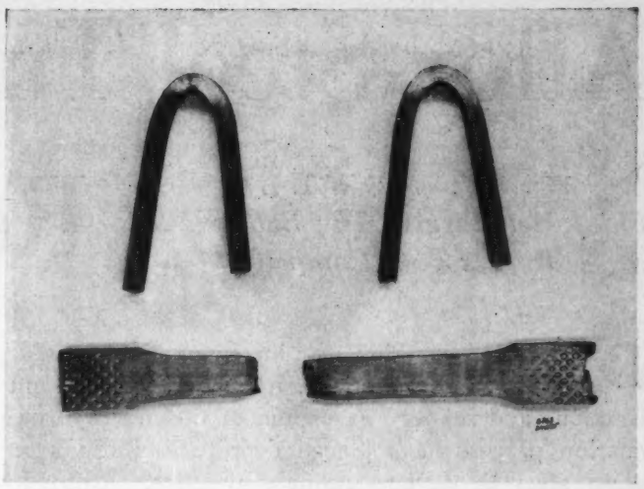


FIGURE 8

Tensile and bend specimens of all weld 18 per cent chrome steel. The elongation in the bend specimen was over 40 per cent without fracture.

The chrome-nickel steels with the proper weldrod can be welded to produce physical and corrosion-resistant properties equal to that of the plate. It has been generally considered that 18 per cent chrome alloy steel can not be welded so as to obtain any appreciable ductility of the weld metal. Recent developments have made possible the welding of this material so as to retain the ductility and corrosion-resistant properties equivalent to that of the plate material. Figure 8 shows the ductility of welds of 18 per cent chrome steel. Nickel and Monel metal are also welded with strength and ductility comparable to that of the plate material.

Table Number 1 gives typical physical properties of welds and plates for some of the load-bearing and corrosion-resistant steels used for vessel construction.

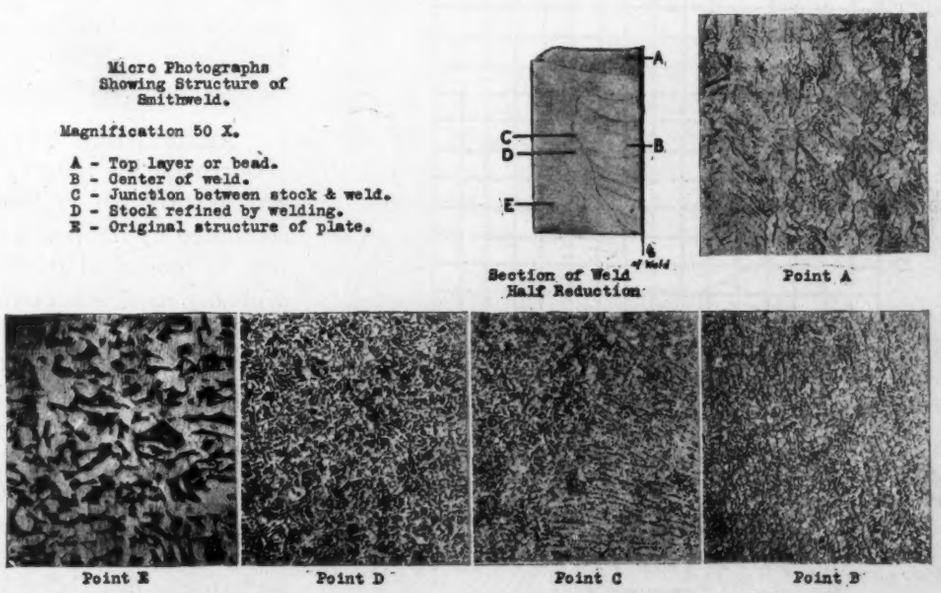


FIGURE 7

Micro photographs showing the structure of the metal in a "Smithweld" and in the adjoining plate. Note the similarity in grain structure between weld and plate, also total absence of oxide and other inclusions.

Alloy Steel Tubes for Refinery Service

H. D. NEWELL
Chief Metallurgist, The Babcock & Wilcox Tube Company

DEMANDS for high anti-knock quality gasoline for the modern motor, for reforming of light fractions and refinery gases and of the new hydrogenation process have placed definite limitations on plain steel in modern refinery practice. Although carbon steel tubes and pipe are still used to the greatest extent for handling "sweet" crudes and where severe temperature and pressure conditions are not prevalent, they are giving way to tubes of alloy steels because of the necessity of frequent shutdowns or replacements of the carbon steel due to corrosion, oxidation, creep, or combinations of these factors, and because of the greater ultimate economy of the alloy materials.

In addition, refinery processes and equipment which were in a rapidly changing period in the industry several years ago, are now standardized and flexible to the extent that they may not become obsolete for periods of five years or longer. This situation permits equipment to be built for permanence and full advantage of alloy materials may be gained without economic loss due to obsolescence. Of paramount importance is the greater economy and safety attending the use of alloy steels by reason of their enhanced corrosion resistance, oxidation resistance and strength at operating temperatures.

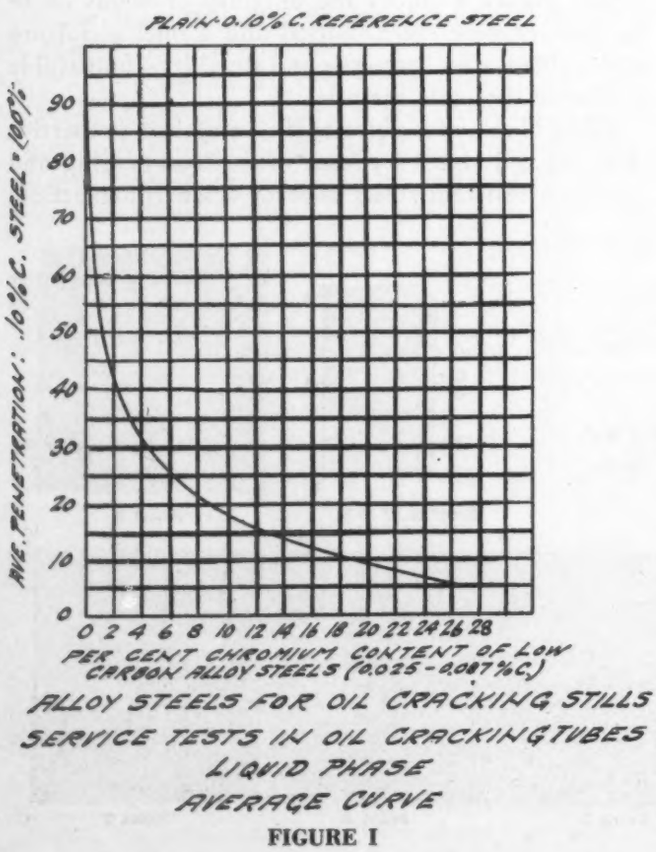


FIGURE I

PAST EXPERIENCE HELPFUL

Refinery engineers and operators have gained experience in the past four or five years in the correct application and use of alloy steels. Until the properties and characteristics of these materials were understood, and certain allowances made in equipment and handling because of these differences in properties, there occurred premature failure and unsatisfactory experiences in certain instances. Older furnaces were not designed for uniform heating of the tubes and in some cases, cleaning periods were delayed too long, resulting in warpage or actual rupture of the tubes. Periodic cleaning and inspection coupled with close control of furnace temperatures and other operating conditions have done much toward insuring satisfactory operation. Such experiences are usual with new materials of construction, and while it cannot be said that all problems are under control or that the ultimate materials have been found for each operating condition, the refinery engineer now has a considerable choice of reliable materials for his use. In fact, it may be said that some of the alloy steels are now out of the experimental class and that a considerable degree of success is attending their use because of increased knowledge and care on the part of both user and manufacturer.

RESISTANCE ENHANCED BY CHROMIUM

Corrosion of refinery equipment, although still a serious problem in the refining industry, has been combated by improved operating conditions and control, by chemical treatment of corrosive oils, and probably most successfully by the use of alloy steels. As is generally known, the addition of the element chromium, to plain steel confers the properties of increased corrosion resistance toward corrosive petroleum products, particularly those containing sulphur compounds. Also greater resistance to oxidation and greater strength at operating temperatures. The enhancement in corrosion resistance is a function of the amount of chromium added. F. N. Speller,[1] in the discussion of a paper by the writer, on

DURING the past year the oil refining industry was faced with the necessity of drastic reduction in operating expense and lower maintenance cost in the upkeep of refinery equipment. In spite of the economic conditions which prevailed in the country, refinery operations were fairly satisfactory when compared to operations in other industries. In consequence of this a fair tonnage of pipe and tubes was purchased and it may be assumed that a considerable proportion of the steel tubular products which went into refinery service was alloy steel used as still tubes, heat exchanger and condenser tubing, vapor lines and other piping.

Although figures for the consumption of alloy steels in the various industries are not available, the trend toward greater use of such materials in the refining industry is indicated by our own production of alloy steel tubular products for refinery service which increased 600 per cent in 1932 over 1931.

In the present article, the writer gives a resume of the properties and general characteristics of the steel alloys in present uses in refinery practice in the form of seamless tubes and pipe with special emphasis on the 4-6 per cent chromium-molybdenum alloy steel which is rapidly gaining favor for furnace tubes because of its economy and admirable properties.

METALLURGICAL SYMPOSIUM

18-8 alloy cracking still tubes,[2] presented to the A.P.I. Division of Refining, April 16, 1931, showed a series of curves based on service tests. These curves depict the relationship between chromium content and corrosion resistance of a series of steel of varying chromium content under conditions of liquid-phase cracking. The average curve from a number of tests in different refineries is reproduced in Figure 1.

Some of the chromium iron alloys, however, are not altogether satisfactory for refinery tube use because of their peculiar tendency to develop extreme brittleness after operation in the temperature range encountered in cracking. This may be said of the alloys containing over about 16 per cent chromium without the addition of nickel. Such alloys are satisfactory as regards to corrosion resistance under severe operating conditions but are entirely unsuitable because of brittleness developed on cooling down. In consequence, very definite chemical composition limits may be set on those alloy steels which are known from experience to be satisfactory.

CHEMICAL COMPOSITION

The chemical compositions of materials now in general use as furnace tubes are given in Table I. Aside from these materials, there are several intermediate alloy steels, some containing small amounts of chromium, between plain carbon steel and the 4-6 per cent chromium group which are attracting attention. Some experimenting is also being done with other alloy steels coming within the so-called stainless field. The use of these newer materials has not been sufficient to permit any statements concerning their economy or properties under service conditions.

Closest to plain steel from the standpoint of composition properties and cost is the carbon-molybdenum steel which is now being used to some extent. This steel first attracted attention for elevated temperature service in Europe where it has been employed as superheater tubes in the Löffler high pressure boiler. It has been recommended for this service by the Vitkovice Mines Steel and Iron Works Corporation,[2] Czechoslovakia, and by Bailey and others in a recent symposium.[3] The addition of molybdenum produces a definite advantage in strength at elevated temperatures over plain steel. Whether any superiority in corrosion or oxidation resistance exists as compared to carbon steel remains to be determined from installations now in service. Such steel, however, is readily weldable and provides additional safety in vapor lines or hot oil piping. It may be used for this purpose to some advantage or as furnace tubes handling non-corrosive cracking stocks at moderate temperatures.

The carbon-molybdenum steel presents about the same structural appearance as ordinary carbon steel and both may be termed pearlitic. See Figures II and III. The molybdenum dissolves in the ferrite, although it also takes some part in the formation of the carbide and is stated to have a refining action on the pearlite. At ordinary temperatures (room temperature) molybdenum has but little effect on the mechanical properties of unheat-treated low carbon steels. In any event, this element is a useful addition for conferring additional strength at elevated temperatures. Complete creep data on this material is not available at present but some data is given later in the article to indicate the creep properties of the metal. Unless specially annealed, it is slightly harder and stronger than carbon steel of equivalent carbon content but for all practical purposes, it may be con-

TABLE I

Composition of Cracking Coil Materials.

ELEMENT	Carbon Steel	Carbon Molybdenum Steel	4-6 Per cent Chromium Steel	4-6 Per cent Chromium-Tungsten Steel	4-6 Per cent Chromium Molybdenum Steel	18-8 Alloy Steel
Carbon	.10 - .20 (a) .15 - .25 (b)	.10 - .25%	.12 - .15 or .20% Max.	.12 - .15 or .20% Max.	.12 - .15 or .20% Max.	0.07% Max.
Manganese	.30 - .60%	.30 - .60%	0.50% Max.	0.50% Max.	0.50% Max.	0.60% Max.
Sulphur	.050% Max.	.045% Max.	0.040% Max.	0.040% Max.	0.040% Max.	0.03% Max.
Phosphorus	.040% Max.	.040% Max.	0.040% Max.	0.040% Max.	0.040% Max.	0.03% Max.
Silicon	*	.10 - .25%	0.50% Max.	0.50% Max.	0.50% Max.	0.75% Max.
Chromium	.....	.....	4.00% - 6.00%	4.00 - 6.00%	4.00 - 6.00%	16.50 - 20.00%
Nickel	.....	.....	.....	.....	.....	7.00 - 10.50%
Molybdenum	.....	.40 - .60%	.....	.....	0.40 - 0.65%	.....
Tungsten	.....	.....	.....	.75 - 1.25%	.....	.....

Grade a }
Grade b } Manufacturers Specification No. 100—Revised Dec., 1932.
*Tubes or pipe shall be killed steel.

sidered as having about the same physical characteristics at ordinary temperatures.

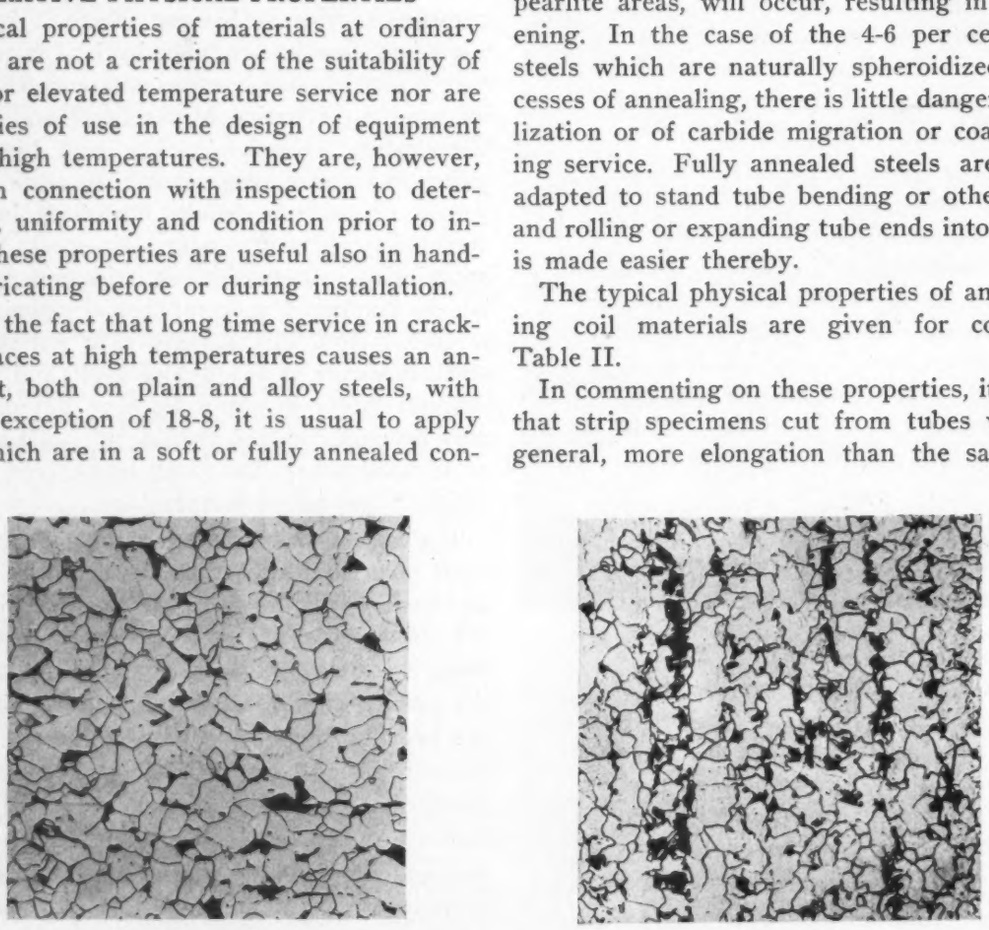
COMPARATIVE PHYSICAL PROPERTIES

The physical properties of materials at ordinary temperatures are not a criterion of the suitability of the metals for elevated temperature service nor are such properties of use in the design of equipment operating at high temperatures. They are, however, of interest in connection with inspection to determine quality, uniformity and condition prior to installation. These properties are useful also in handling and fabricating before or during installation.

Because of the fact that long time service in cracking coil furnaces at high temperatures causes an annealing effect, both on plain and alloy steels, with the possible exception of 18-8, it is usual to apply still tubes which are in a soft or fully annealed condition. This results in having a stabilized material enter service, although even in such case, slight changes in structure, such as spheroidizing of the pearlite areas, will occur, resulting in further softening. In the case of the 4-6 per cent chromium steels which are naturally spheroidized in the processes of annealing, there is little danger of recrystallization or of carbide migration or coalescence during service. Fully annealed steels are also better adapted to stand tube bending or other fabrication, and rolling or expanding tube ends into header boxes is made easier thereby.

The typical physical properties of annealed cracking coil materials are given for comparison in Table II.

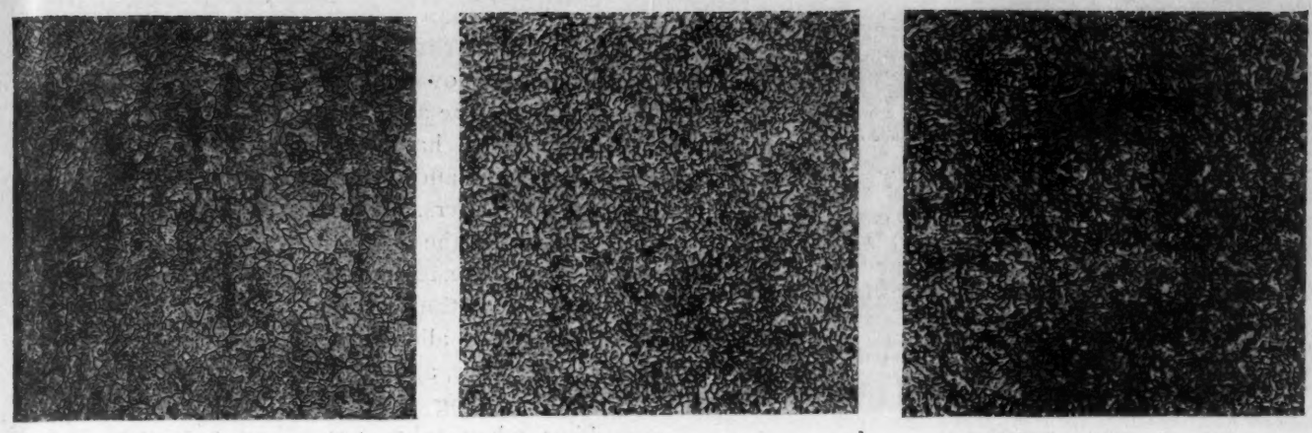
In commenting on these properties, it may be said that strip specimens cut from tubes will show, in general, more elongation than the same materials



(a) *(b)*

FIGURES II and III

Typical Microstructure of:
(a)—Carbon Steel Cracking Still Tube.
(b)—Carbon-Molybdenum Steel Cracking Still Tube.
X 100 ***Etch: Nital***



(a) *(b)* *(c)*

FIGURE IV

Typical Microstructure of 4-6 per cent chromium steels, annealed.
(a)—Plain 4-6% chromium.
(b)—4-6% chromium, .50% molybdenum.
(c)—4-6% chromium, 1.00% tungsten
X 100 ***Etch—Nital.***

tested in the form of standard .505-inch diameter test pieces. This is due to the form and dimensions of the test pieces, however, compromise 1½ inches wide strip specimens are acceptable because .505-inch round specimens are not obtainable except from tubes of exceptionally heavy wall. It might also be said that 4-6 per cent chromium alloy steels, in common with many other alloy steels, do not exhibit well defined yield points as do the carbon or carbon-molybdenum steels. No drop of the beam of the testing machine occurs during testing and as a result, yield points are usually taken with dividers set at 0.5 per cent of the gauge length, which gives a value which may be termed a proof stress.

ALLOY STEELS OF 4-6 PER CENT CHROMIUM TYPE

There has been a very definite trend, particularly within the past year, toward the use of alloy steel tubes containing 4-6 per cent chromium. Such alloy steels are being used with decided success as cracking still tubes, vapor lines, hot oil piping, and heat exchanger tubes. Containing sufficient chromium to be fairly resistant toward moderately and even fairly corrosive oils, these alloys are proving economical and useful. Service reports show corrosion resistance of these materials to be from four to 10 times that of carbon steel, depending on the nature of oil handled, velocity, temperature, and other factors. Combined with some advantage in elevated temperature strength, particularly when containing molybdenum or tungsten, and being more resistant to oxidation than plain steel, the 4-6 per cent chromium steels are finding an exceptionally useful place in modern refining. They are not in any sense stainless because they do not contain sufficient chromium to develop the passive metal surface characteristic of true stainless steels. They are highly resistant to sulphide corrosion, however, and the rapid adoption of these alloys indicate their economy and usefulness.

Because of the increasing interest prevalent at this time in these alloys, a short review of their characteristics is given. Steels of this class are characterized by their intensely air hardening nature when cooled from temperatures above the transformation point of

TABLE II
Typical Physical Properties of Cracking Coil Materials.*

MATERIAL	Ultimate Strength Lbs. per sq.in.	Yield Point Lbs. per sq.in.	Elongation %in 2"	Brinell Hardness	Charpy Impact Ft. Lbs.†
Carbon Steel	58,900	35,750	48.0	113	46.0
Carbon-Molybdenum	65,800	41,200	45.0	126	.....
4-6% Chromium	62,270	28,500	46.0	131	46.0
4-6% Chromium .50% Molybdenum	73,200	33,400	50.0	148	56.0
4-6% Chromium 1.00 Tungsten	75,500	39,100	43.0	156	50.0
18-8 Alloy	95,600	40,100	60.0	175	84.0

*Typical values selected from numerous tests on 1½" wide strips cut from annealed tubes.
†A.S.S.T.—.394" square specimen, keyhole notch.

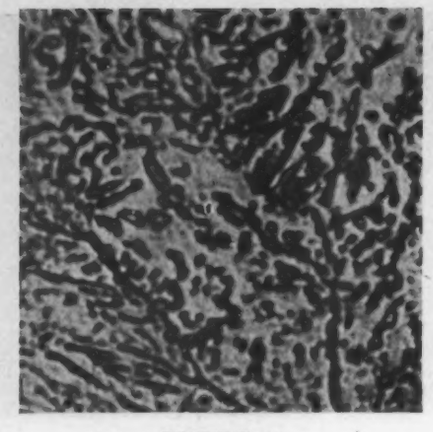


FIGURE V

Microstructure, at high magnification, of annealed 4-6 percent chromium-molybdenum steel.
X 2000 Etch—Nital.

about 1500°F. This air hardening is proportional to both carbon and chromium content and is even evident to an appreciable extent when the carbon content is less than 0.1 per cent.

Careful annealing after hot working, forging, Vanstoning or welding is requisite and this is accomplished by heating to 1575-1625°F., and cooling to a black heat in the furnace at a comparatively slow rate. Reheating at 1350-1400°F. for several hours followed by cooling in air suffices for a partial annealing, but such treatment will not produce full softness nor ductility. Although slightly harder and stronger than low carbon steel, these steels have excellent ductility and toughness in the annealed state and will stand practically all the working and deformation of the usual low carbon steel tubes or pipe.

Welding of these alloys is a rather difficult task, and where attempted it should be immediately followed by annealing to prevent stress cracking in the weld areas due to strains set up in the air hardened metal. Low carbon, under .12 per cent, should be selected where welding is contemplated, because of its lesser air-hardening ability. In some cases, 18-8 welding wire applied by arc welding, has been successfully used for seal welding of flanges on hot oil lines.

Structurally, the 4-6 per cent chromium alloys may be termed pearlitic steels, but in the fully annealed condition their microstructure is composed of chromium bearing ferrite grains with carbide particles in a spheroidized state. Both tungsten and molybdenum have a grain refining action and the grain structure of the steels containing these additional elements is somewhat finer than that of the plain 4-6 per cent chromium steel. Typical examples of these materials in the annealed condition are shown in Figure IV. At high magnification, the globular or spheroidized nature of the carbides is evident as is shown in Figure V of the molybdenum containing alloy.

Aside from the tendency to occasionally develop cold brittleness, which is most pronounced in winter time operation, and having strength properties not much greater than carbon steel at elevated temperatures, the plain chromium type has given a good account of itself over several years experience in refinery work. The addition of tungsten, (usually 0.75-1.25 per cent) has served to increase the creep strength of the alloy and has been used to advantage by some engineers. Experience shows that tungsten fails to correct the cold brittle character of the alloy, and may even exaggerate this condition. It might be explained that the brittleness referred to is present only when the alloy is slowly cooled from operating temperature, and in certain instances shock from cleaner or rolling tools has been known to cause cracking when tubes are below a temperature of 200°F. As temperatures decrease from 200°F to 70F°, or below, the brittleness becomes more pronounced, and consequently most cracking trouble has been reported in the winter, and to the greatest extent in northern refineries.

In metallurgical parlance, this cold brittleness is known as "temper brittleness", a common occurrence among many of the low alloy steels, and it may result on slowly cooling certain alloy steels from a tempering temperature. It may be entirely prevented by rapidly cooling or quenching from a temperature of 1000°F., or above. Such proceedure can not be conveniently done in cracking coil furnaces. Consequently, it is good practice to clean or reroll the plain chromium or tungsten types when the metal temperatures of the tubes are above about 200°F. A temperature above 200°F. may be considered a safe point with full toughness restored to the metal.

The susceptibility of steels to this type of brittleness may be determined by means of the impact test.[4] Although in some cases the impact test fails to detect loss in impact value in tubes which have become brittle enough to crack when cleaned cold. In all cases, the brittleness may be made evident by flattening rings cut from the embrittled tubes after first chilling the test samples in cold water. Just why the impact test fails to measure the loss of shock resistance and the ring flattening test shows it up is the subject of an investigation now in progress.

EFFECT OF MOLYBDENUM

The company with which the writer is connected was, so far as he is aware, the first of the producing companies to advocate the addition of molybdenum to the 4-6 per cent chromium steel. This addition of a small quantity of molybdenum (.40-.65 per cent) results in several distinct advantages which may be enumerated as follows:

(1) It adds appreciably to the high temperature (creep) strength of the alloy.

(2) It removes the tendency toward temper-brittleness prevalent in cooling in the plain and tungsten 4-6 per cent chromium steels, providing the heat treatment has been properly done.

(3) It adds to the corrosion resistance of the alloy.

These benefits are secured at but small increase in

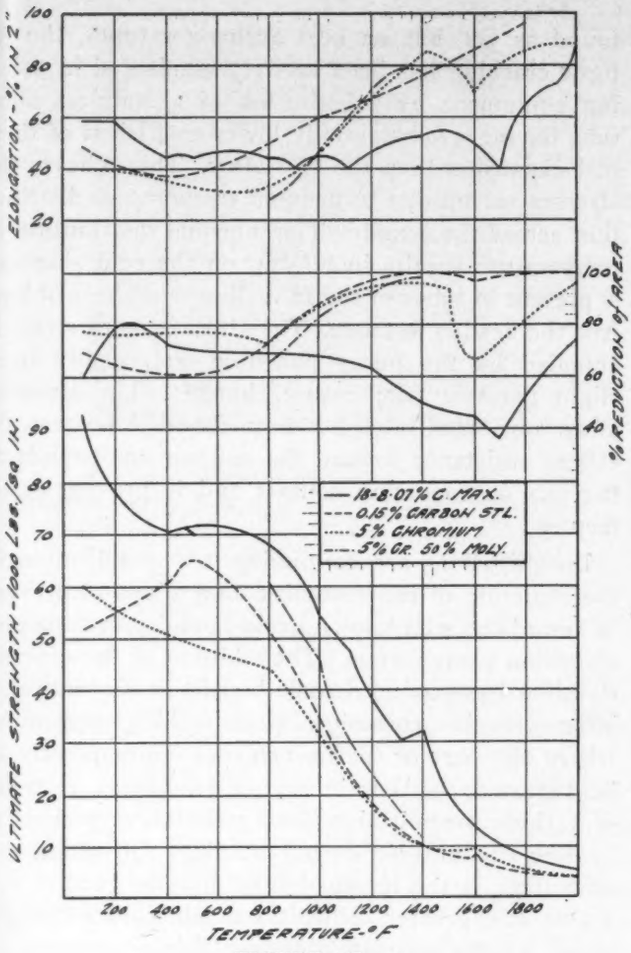


FIGURE VI

cost over the plain chromium type and at a lessor cost than for the tungsten addition and it is felt that the greater high temperature strength and reliability of this combination make it a distinctly favored one for general use.

Proof of the efficacy of molybdenum as a preventive of cold cracking from temper-brittleness lies in the number of tubes in service without a single case of cracking having been reported. The increase in corrosion-resistance under various operating conditions remains to be determined, but sufficient results have been reported to permit saying that the molybdenum steel offers some advantage over the plain chromium type.

The effect of molybdenum on the short-time elevated temperature properties as compared with plain chromium, 18-8 and carbon steel are shown in Figure VI. These tests were all made under the same conditions of test on fully annealed materials and are strictly comparable. As is commonly known, tests of this nature are made by surrounding the specimen with a tubular electric resistance furnace, mounted between the heads of a tensile testing machine, heating the test piece to the required temperature followed by pulling at a slow and evenly applied rate. The entire test is accomplished within several minutes after the specimen has become thoroughly and evenly heated; hence, the name "short-time" elevated temperature tests. Data obtained in this manner is indicative of the properties of the materials to a certain extent but can not be reliably used for design purposes.

STAINLESS 18 PER CENT CHROMIUM—8 PER CENT NICKEL ALLOYS

Stainless 18-8 cracking still tubes have not found much favor in recent installations. This is due in part to the fact that a considerable percentage of the crude being processed at present is "East Texas" or other sweet crude and the extreme corrosion resistance possessed by this highly alloyed steel is not necessary. Another factor militating against the use of such material has been its high initial cost which can only be justified where the temperature-pressure conditions are extreme, or where excessively sour crudes are being handled. It should not be inferred that this situation has any bearing on the suitability of the 18-8 alloy for still tube service, as the past three or four years have proven the worth of the 18-8 tube under extreme operating conditions. Many thousands of such tubes are completing 20,000 and even 30,000 hours on stream with no great loss from internal corrosion. In some few cases, the external surfaces of the tubes are suffering from some scaling due to oxidizing sulphur compounds in the gases of combustion. This is due to using fuels high in sulphur content. In one case in particular, the external surfaces of the tubes have shown considerable scaling during about three years contact with the product of combustion from refinery gas carrying 1.25-1.75 per cent sulphur.

Design of furnaces and methods of operation which permit satisfactory performance of these 18-8 tubes have been arrived at and now full advantage of the characteristics of the alloy can be secured. In most cases such tubes are installed in radiant sections only with lesser alloy or plain steel tubes in the convection parts of the furnaces.

The 18-8 alloy tube has found a valuable field in transfer or vapor lines where its high strength and ductility coupled with maximum resistance to corrosion make it the safest and most satisfactory material available for such service. In this service, tubes are not subject to heat input and consequently no specially designed furnaces or careful operating practices are required.

The 18-8 cracking coil tube has shown exceptional life and proved its economy in handling corrosive California gas-oils and West Texas crudes. It is also used for handling Venezuela crude in cracking coils. This corrosion resistant alloy steel offers the maximum at present obtainable in tube form in corrosion resistance and oxidation resistance and in creep strength at elevated temperatures. See Table III for comparative creep properties.

It has not, however, been altogether successful in heat exchanger and condenser tube installations. The design of the exchanger or condenser greatly influ-

TABLE III

Creep Stress Data for Cracking Coil Tube Materials.*

1 Per cent in 10,000 Hours

Temp. °F.	0.08% Carbon Steel	0.20% Carbon Steel	4-6% Chromium Steel	4-6% Cr. .50% Moly. Steel	18-8 (.07% C.) Max.
650	.....	.....	.....	.....	56,000
800	12,700	.....	22,000	.....	.....
900	6,300	10,500	9,200	17,900	24,000
1,000	3,300	3,900	6,000	9,200	18,300
1,100	825	1,250	2,000	4,800	11,550
1,200	.....	550	840	1,800	6,600
1,350	.....	.....	.....	.....	2,500

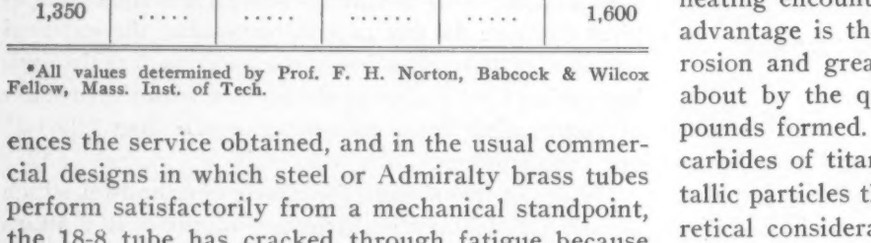
1 Per cent in 100,000 Hours

650	.....	.....	.....	.....	35,500
800	6,750	8,600	10,200	.....	25,300
900	4,900	7,800	5,100	15,000	18,000
1,000	2,800	3,200	3,300	7,200	11,500
1,100	630	925	1,320	2,400	7,100
1,200	70	440	450	900	4,250
1,350	.....	.....	.....	.....	1,600

*All values determined by Prof. F. H. Norton, Babcock & Wilcox Fellow, Mass. Inst. of Tech.

ences the service obtained, and in the usual commercial designs in which steel or Admiralty brass tubes perform satisfactorily from a mechanical standpoint, the 18-8 tube has cracked through fatigue because sufficient freedom for expansion has not been allowed. In some cases this fatigue action has been accelerated by corrosion resulting in the phenomenon of "corrosion-fatigue". Cooling water, especially that of salt or brackish nature, usually causes pitting which results in eventual failure of the tubes. No very satisfactory answer to this problem has been found as yet, but on heat exchanger tubes, the fatigue cracking has been entirely eliminated in existing equipment by substitution of a stainless alloy tube having a substantially lower coefficient of thermal expansion than the 18-8 alloy. This relieves the stresses set up due to unequal temperature distribution across the bundle. This unequal distribution of temperature results in tension on the cold side and is present in tubes of the 18-8 alloy regardless of how free the head is to move. The alternation of stress is supplied by the pump pulsation or possibly from slight periodic temperature changes. The stainless alloy tube substituted has been found to possess excellent resistance toward the sulphur compounds of the oils or vapors in contact and is proving satisfactory.

Investigations are continuing on stabilization of the structure of the austenitic 18-8 alloys to prevent or retard the well known grain boundry carbide precipitation phenomenon. The addition of the element titanium has produced some benefit in prevention of intercrystalline corrosion after welding operations where the part or parts can not subsequently be heat-treated. This is in part, a temporary restraint of carbide precipitation during the short periods of heating encountered during welding. Offsetting this advantage is the lessened resistance to general corrosion and greater difficulty of fabrication brought about by the quantities of insoluble titanium compounds formed. These oxides, nitrides and possibly carbides of titanium, remain distributed as non-metallic particles throughout the metal and, from theoretical considerations, might be termed undesirable. As examples, the polished unetched structure of titanium-free 18-8 tube material as ordinarily used in cracking tubes and that of a titanium containing material are shown for comparison in Figure VII. The use of titanium treated 18-8 for elevated temperature service has not progressed far enough at present to permit any statements regarding advantages of metal so treated. It is believed that titanium functions, in part at least, as a grain refiner in 18-8 alloys, providing mechanical obstruction to grain-growth due to the presence of numerous non-metallic particles. The detrimental effect of large grains in 18-8 alloys for elevated temperature service has been previously shown[1] and tubes for such service are now processed by methods (Patent applied for), designed to produce maximum grain refinement. Thus, the grain refining action of titanium may be secured by other means and without the introduction of foreign particles into



(a) *(b)*

FIGURE VII

Microstructure, Unetched X 100
(a)—18-8 Cracking Still Tube.
(b)—18-8 Containing Titanium Addition

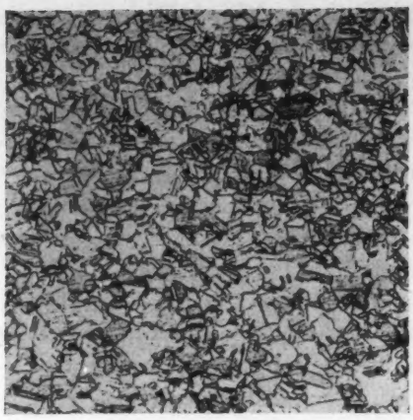


FIGURE VIII

Microstructure of 18-8 alloy tube processed by methods developed to produce a "fine-grained" alloy. Etch: Chrome-regia X 100

the metal. As grain-growth producing temperatures for the alloy are substantially above the usual operating ranges, the fine grained structure produced during manufacture of the tube is permanent under service conditions. Figure VIII shows the fine-grained structure of an 18-8 tube processed by this special method and selected at random from a recent shipment.

CREEP PROPERTIES

No discussion of materials intended for elevated temperature service can be termed complete without consideration of the effect of stress and high temperature on materials while maintained for long periods. For many years the tensile strength at room temperature of an engineering material has been regarded as the most important criterion on which to estimate its value in service, but it is known that above a certain temperature peculiar to each material, the breaking strength is not disclosed by the ordinary tensile test and engineers are now pressing for information on satisfactory basic stresses for elevated temperatures.

These design stresses are usually based on the creep rate of the alloy at the various temperatures. Creep is defined by Tapsell[6] as the deformation of a material occurring with time under and due to an externally applied stress whether the deformation be of the nature of plastic or viscous flow. Creep may result from any form of applied stress but the existing information relates almost exclusively to tensile creep. In general, these creep rates or values are determined by maintaining specimens under load and temperature for long periods of time. The average rates of deformation for certain time periods are then observed and flow rates are obtained from which are evaluated safe stresses for operation at the high temperatures. These creep values are usually expressed in terms of one per cent elongation in 10,000 hours or in many cases, in 100,000 hours. The permissible extension and the probable life of the equipment based on safety factors, corrosion rates, obsolescence, etc., then govern the stress value selected for design.

There is still much to be learned both of the fundamental nature of creep flow and of suitable methods for the determination of creep rates. It is not intended to further this discussion here because it is recognized that much remains to be done in standardizing testing methods and in obtaining reliable data for design purpose and in learning the proper way to apply such data. In the meantime, refinery apparatus and other high temperature equipment must operate and in many cases use of existing data is being made in a comprehensible manner.

For the past seven years The Babcock & Wilcox Company, and The Babcock & Wilcox Tube Company, have conducted a large number of creep test on various materials under the direction of Professor F. H. Norton of the Massachusetts Institute of Technology. The methods and apparatus used by Norton have been described.[7-8] Curves showing creep rates of annealed plain 4-6 per cent chromium steel versus annealed 4-6 per cent chromium-molybdenum steel .20 per cent maximum carbon grades are given in Figure IX. The beneficial effect of molybdenum is quite apparent. These data as well as the creep curves for 18-8 alloy given in Figure X, are based on Professor Norton's work. The tests are in all cases com-

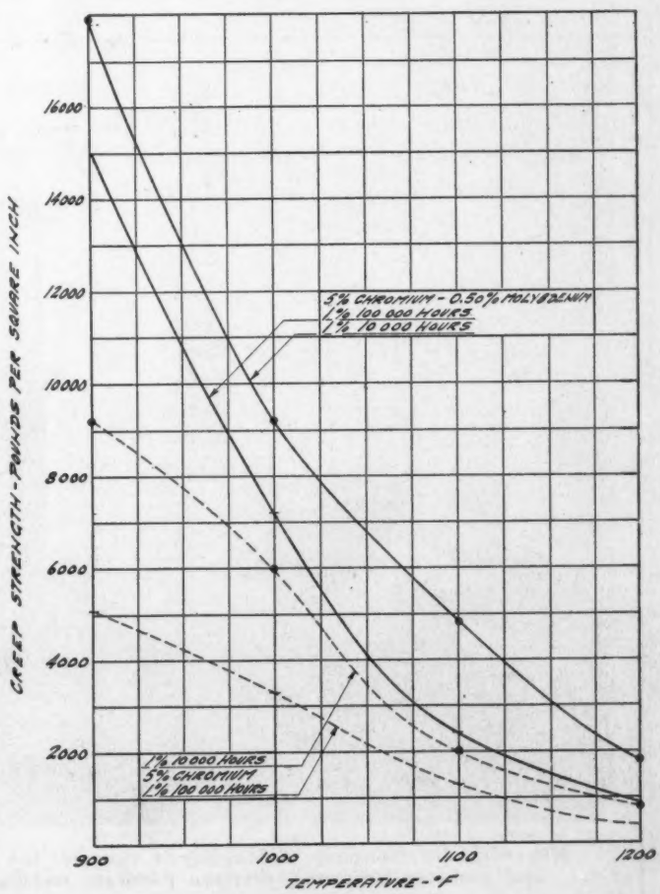


FIGURE IX

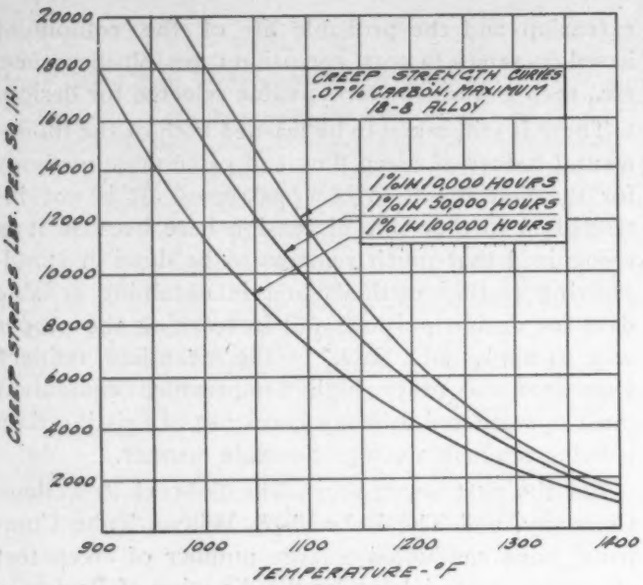


FIGURE X

parable, having been done on the same equipment by the same investigator.

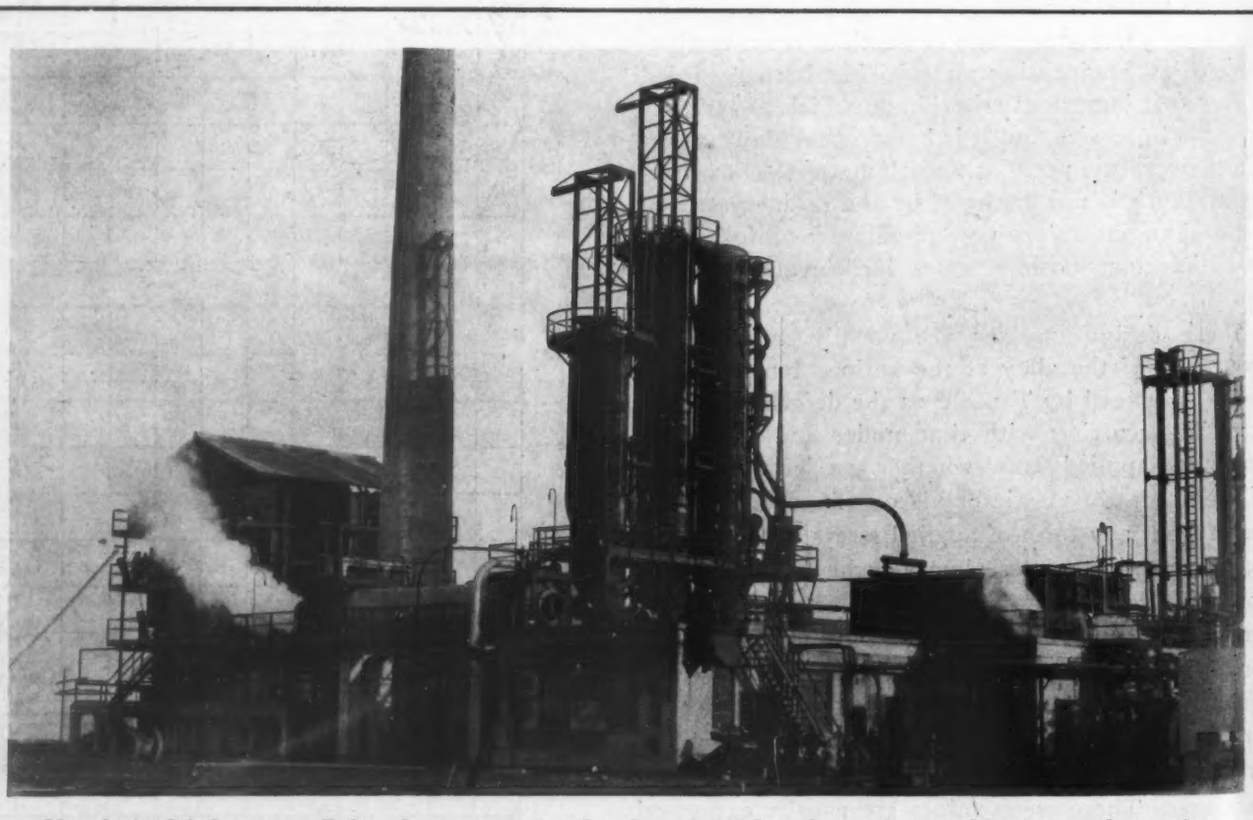
Additional data on creep of materials for cracking coil tubes from Professor Norton are given in Table III, which gives stress values in pounds per square inch for both one per cent in 10,000 and one per cent in 100,000 hours.

Apparently molybdenum acts to increase the creep strength of plain carbon steel in a ratio equivalent to the improvement shown in the 4-6 per cent chromium type. Clarke and White, in a recent article[9], report carbon-molybdenum steel as having 7200 pounds per square inch creep strength for one per cent elongation in 100,000 hours at 1000°F. As may be noted in Table III, this is quite superior to the creep values shown for carbon steels at the same temperature.

The design of tubes suitable for service at various elevated temperatures is a somewhat controversial subject, and such a discussion can not be presented here. It is sufficient to say that a number of factors are involved and that accurate information is a necessity. Maximum tube wall temperature, maximum pressure, transfer rate, conductivity, corrosion factor, creep values, etc., are essential. With such information available, the correct thickness of the tube for any given set of operating conditions may be arrived at.

SUMMARY

The use of alloy steels and other corrosion resistant materials is constantly increasing in the refining industry. The refinery engineer now has a considerable choice in the selection of alloy steels for cracking coil tubes, refinery piping and heat exchanger tubes. The appropriate material for use must be selected with due consideration of its economy, based on corrosion-resistance, strength characteristics, general properties, and reliability. This in turn calls for a thorough knowledge of refinery practices and of the materials themselves which necessitates close cooperation between manufacturer and



Mitsubishi Oil Company, Tokio, Japan, operates the above 3,000-barrel capacity, combination crude topping and cracking unit and pressure distillate stabilization system. Installed by M. W. Kellogg Company.

user. Development of new materials and improvement of present ones is thus made possible.

At present there is a definite trend toward the use of alloy steel tubes and pipe of the 4-6 per cent chromium type. Such material is intermediate in cost and has excellent properties and corrosion resistance. Where corrosion alone is concerned, the plain type can be employed, but if greater strength properties are also required, the addition of molybdenum is warranted. The benefits to be derived from the molybdenum addition are pointed out and the increase in elevated temperature strength obtained by such an addition is shown by creep data recently made available. One of the principal effects of molybdenum lies in the prevention of cold brittleness which occassionally is encountered in the other types.

For extreme conditions of temperature, pressure and/or corrosion, the use of 18-8 alloy is justified, and tubes of such material have been used with decided success for the past several years. The 18-8 alloy provides, in the tube form, the maximum obtainable in creep strength, corrosion, and oxidation resistance. The characteristics of this alloy are now fairly well known and with certain allowances in equipment and with careful operating practice, tubes of such material may be economically and safely used.

For mild or non-corrosive cracking stocks or crudes, the addition of molybdenum to plain carbon steel produces a decided improvement in elevated temperature strength properties. Tubes of such material are obtainable at normal cost and the use of such material should increase where additional strength properties are required over that possessed by plain steel.

In conclusion, the writer feels that economies made possible through reduced corrosion losses, lower maintenance charges, less shut-down time for replacement, and better products are all factors tending to increase the use of alloy steels in the refinery. The limitations of ordinary steel in modern refining make necessary the substitution of alloys. Continued improvement in present materials and development of new ones can be expected through cooperation between manufacturer and user.

REFERENCES AND SELECTED BIBLIOGRAPHY

[1]Newell, H. D., American Petroleum Institute, Mid-Year Division of Refining, April, 1931. "The 18-8 Iron-Chromium-Nickel Alloy with Particular Reference to its Characteristics for Cracking Coil Service."

[2]Gregg, J. L., McGraw-Hill Book Company, 1932, "The Alloys of Iron and Molybdenum."

[3]A.S.T.M.—A.S.M.E., 1931. "Symposium on Effect of Temperature on the Properties of Metals."

[4]Greaves & Jones, Journal Iron and Steel Institute, 1925, Vol. CXI No. 1. "Temper Brittleness of Steel, Susceptibility to Temper Brittleness in Relation to Chemical Composition."

[5]Newell, H. D., Transactions, A.S.S.T. Vol. 19, 1931-1932. "Influence of Grain-Size on the Properties and Corrosion Resistance of the 18-8 Iron-Chromium-Nickel Alloy for Elevated Temperature Service."

[6]Tapsell, H. J., Oxford University Press, 1931—"Creep of Metals."

[7]Norton, F. H., McGraw-Hill Book Company, Inc., 1929, "The Creep of Steel at High Temperatures."

[8]Norton, F. H. and Romer, J. B., Proceedings—A.S.T.M. Committee Reports Tentative Standards, Part 1—1931. Report of Joint Research Committee on Effect of Temperature on Properties of Metals. Appendix III.

[9]White, A. E., and Clark, C. L., N.E.L.A. Publication No. 220, May, 1932. "Higher Steam Temperatures and Pressures."

[10]Bulletin T-1—The Babcock & Wilcox Tube Company, 1932. "4-6 Per Cent Chromium Steel Tubes and Pipe."

[11]Whitman and Roberts, Bulletin American Petroleum Institute, Jan., 1930—Section III. "Pressure Still Corrosion."

[12]Chairmens' Report, Bulletin American Petroleum Institute, Dec., 1930—Section III. "Refinery and Marine Corrosion."

[13]Dorsey S. F., Metallurgia 3, No. 13—1930. "Tube Materials for High Pressure Water Tube Boilers."

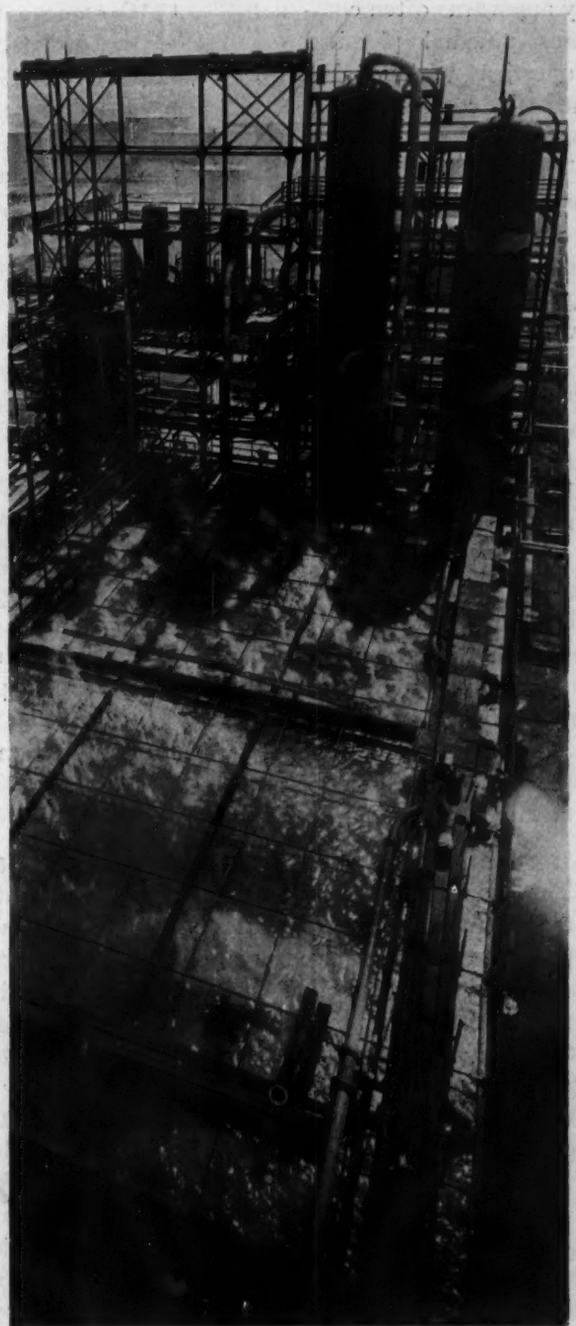
[14]Boyer, M. W., Chem. Met. Engr. 37, No. 12—741-5 (1930) "Hydrogenation Adapted to the Oil Refinery."

[15]Haslam and Russell, Ind. Eng. Chem. 22, No. 10—1030-37 (1930) "Hydrogenation of Petroleum."

[16]Wright, E. C., before the metallurgical meeting, Mid-Continent Division, A.S.M.E., Tulsa, Oct. 4-5, 1932. "Selection of Ferrous Metals Used in Refineries Has Developed to Paramount Importance."

[17]Malcolm, V. T., before the Metallurgical meeting, Mid-Continent Division, A.S.M.E., Tulsa, Oct. 4-5, 1932. "The Selection of Materials for High Pressure and High Temperature Work in Oil Refineries."

[18]Speller, F. N. Section 3, 13th annual meeting American Petroleum Institute, Nov. 14 to 17, 1932, Division of Refining. "Development and Trend in Ferrous Alloys for High Temperature Service."



Panorama view of Cracking Coil No. 1, Bayway refinery of Standard Oil Company (New Jersey) taken from the fractionating equipment.

Alloy Steels *in* Refinery Construction

DR. F. N. SPELLER
Director, Department of Metallurgy and Research, National Tube Company

TO some extent the material incorporated in the accompanying discussion has been abstracted and rearranged by the author from matter included in his recent paper before the American Petroleum Institute, Division of Refining. To this earlier work, Dr. Speller has added later information and a recent bibliography. Space does not permit more than an abstract of this subject and further details are available from the various articles referred to at the end of the article.

METALLURGICAL SYMPOSIUM

THE ideal metal for many parts of refinery apparatus often combines unusual physical properties with resistance to corrosion and abrasion.

The principal types of corrosion in refinery equipment may be classified according to temperature ranges, as follows:

1. At the lower temperatures under 400°F.: the dissociation of calcium and magnesium chlorides in the stills and action of brackish water in condensers and cooling systems. This is accelerated by the presence of hydrogen sulphide, or by sulphuric acid, sulphur dioxide and sulphonated hydrocarbons produced in purification operations.

2. At temperatures above 400°F.: decomposition of sulphur compounds in the crude.

3. High temperature oxidation by furnace gases.

PRINCIPLES OF CORROSION-PROTECTION

The process by which metals are made resistant to corrosion in solutions or in gases at high temperatures is now generally recognized as one in which a protective film is formed by reaction between the metal and its environment, usually by oxidation. The film that separates the metal from its environment may be built up mainly of corrosion products from the metal; or by reaction between the metal and some essential material in the environment, such as chromium salts; or by both of these influences. The protective property of films (for example, the so-called "passivifying" effect) varies mainly with the nature and concentration of attacking elements and the temperature. All films appear to be more or less porous to certain elements. However, some elements, such as chlorine, penetrate oxide films much more readily than others, such as sulfur and its compounds.

The character and density of the film depend, apparently, upon the concentration and properties of film-building material available—whether it be originally in the metal or in the surrounding environment. For instance, 50 p.p.m. sodium chromate are sufficient to maintain indefinitely the bright surface of iron when immersed in distilled water at normal temperature. With 500 p.p.m. of sodium chloride in solution, this amount of chromate will not be nearly so protective. We have found, however, that, by increasing the concentration of sodium chromate in solution, satisfactory protection can be obtained against the penetrating chlorine ions. For example at a chloride concentration of 30,000 p.p.m., a chromate concentration of 2500 p.p.m. is required to maintain a fairly protective skin on the metal. So also with metal alloys, the environment determines the degree and cost of protection required.

The metals that may be alloyed with iron to aid in building up these self-protective films at reasonable cost are relatively few; and include principally chromium, nickel, silicon, molybdenum, and aluminum. Of these, chromium is by far the most important under most conditions—although chromium and chromium-nickel steels are not resistant in some environments, such as hydrochloric acid; hence, we are forced to the conclusion that there is, in all probability, no one metal that can be economically used to resist oxidation and other forms of corrosion under all conditions, especially at elevated temperatures. The influence of chromium alone is illustrated under several different conditions in Figures 1 and 2.

Evidently, then, the problem is to find the metal best suited for each type of corrosion at the lowest cost. The character and resistance of the surface film must be such as to exclude most of the ions that bombard the metal surface, and the properties of the film must

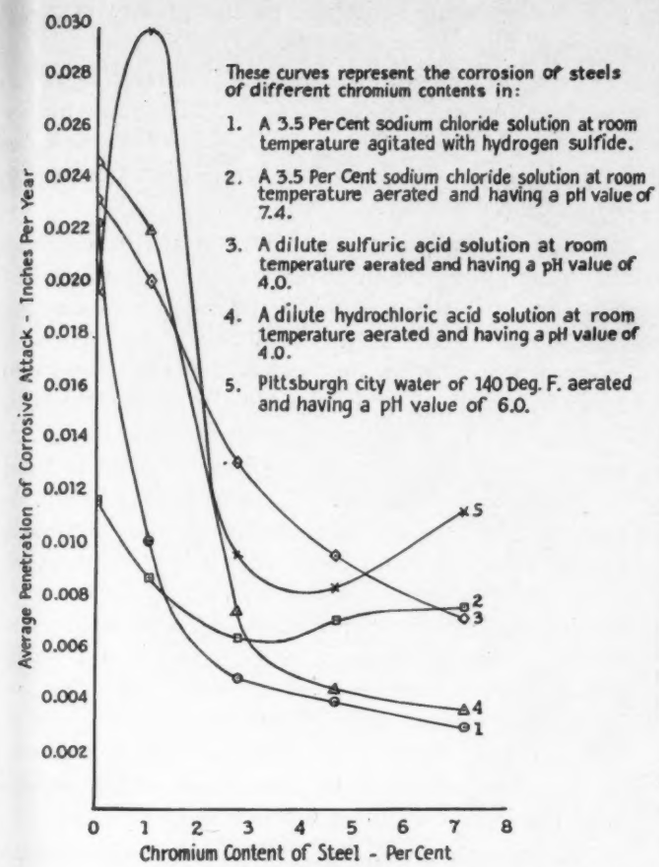

These curves represent the corrosion of steels of different chromium contents in:
1. A 3.5 Per Cent sodium chloride solution at room temperature agitated with hydrogen sulfide.
2. A 3.5 Per Cent sodium chloride solution at room temperature aerated and having a pH value of 7.4.
3. A dilute sulfuric acid solution at room temperature aerated and having a pH value of 4.0.
4. A dilute hydrochloric acid solution at room temperature aerated and having a pH value of 4.0.
5. Pittsburgh city water of 140 Deg. F. aerated and having a pH value of 6.0.
Average Penetration of Corrosive Attack - Inches Per Year
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0 1 2 3 4 5 6 7 8
Chromium Content of Steel - Per Cent

FIGURE 1

Curves from Laboratory Tests Showing Corrosion of Carbon Steels Compared with Steels of Varying Chromium Content.

be varied accordingly to meet different conditions of attack. Furthermore, it is important that they form a film rapidly, so that when damaged the break will be repaired before much waste of metal takes place. The rate of corrosion of chromium steels is about the same as that of ordinary plain carbon steels for the first few moments of exposure, but decreases rapidly in a short time, as illustrated in Figure 3.

So far no metal of reasonable cost has been found that protects itself from concentrated chlorides at high temperatures.

The presence of a film has been definitely proved in many cases by separating the film from the metal and mounting it so that it becomes more visible and so that it can be examined under the microscope, and also by changes in metal potential as the film forms.

It has been shown that passivity is due to film protection, and that an invisible oxide film forms on ordinary iron at normal temperature. The highly protective films that form on stainless iron or aluminum are much thinner than those formed on ordinary iron under the same conditions. There is reason to think that some of these films are of molecular thickness.

In developing corrosion-resistant metals it is, of course, important in most cases to consider the physical properties of the metal as well as its chemical resistance; for this reason we shall now discuss briefly the effect of elevated temperatures on the structure and physical properties of some alloy steels commonly used.

INFLUENCE OF ELEVATED TEMPERATURE ON PHYSICAL PROPERTIES AND STRUCTURE OF FERROUS ALLOYS

More progress has been made in the development of metals resistant to corrosion than in the study of properties of metals after prolonged exposure to high temperatures. In fact, some corrosion-resistance might well be sacrificed in the higher chromium alloys, if necessary, to secure more desirable physical properties.

The selection of the best metal for high temperatures, as well as other service, is usually a compromise with due consideration to minimum physical properties under service, environment, fabrication, corrosion-resistance, resistance to abrasion, and relative cost.

It is important that the designing engineer recognize the fundamental limitations of metals at high temperatures with respect to the effect of heat on their phyisical properties.

It is now well known that carbon and alloy steels that are permanently stable at normal temperatures may undergo changes in structure and physical properties at higher temperatures but below their critical points. These changes are, of course, of fundamental importance to refinery engineers. Information on these changes is at present rather incomplete on account of the long time required to make tests. For example, the well-known lamellar pearlite in ordinary structural steels is changed to a globular state when the steel is heated to about 1300°F. for long periods. This transformation is termed "spheroidization." The strength of the metal at normal and at elevated temperatures is somewhat reduced by this change in structure.

Ferrous alloys of the austenitic type are also suscept-

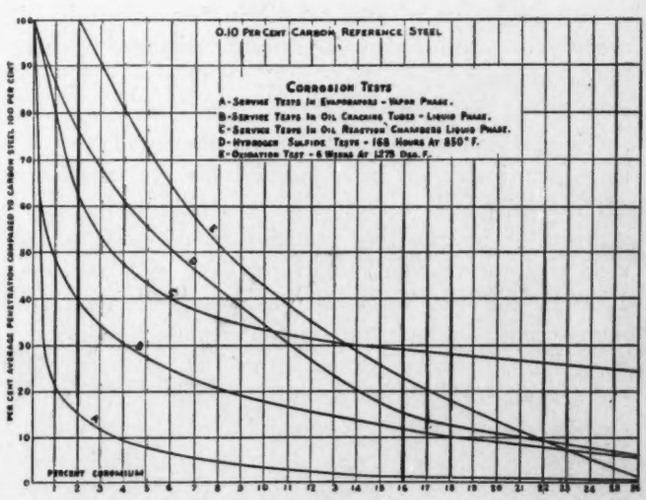

0.10 Per Cent Carbon Reference Steel
Corrosion Tests
A - Service Tests in Evaporators - Vapor Phase.
B - Service Tests in Oil Cracking Tubes - Liquid Phase.
C - Service Tests in Oil Reaction Chambers Liquid Phase.
D - Hydrogen Sulfide Tests - 168 Hours at 850° F.
E - Oxidation Test - 6 Weeks at 1275 Deg. F.
Per Cent Average Penetration Compared to Carbon Steel 100 Per Cent
Per Cent Chromium

FIGURE 2

Corrosion-Resistance of Chromium Alloy Steels Compared with Regular Carbon Steel. Summary of Tests in Operating Units in 10 Refineries on 15 Different Alloys. Curves D and E Are Laboratory Tests.

CALORIZING

Contributed by B. J. Sayles, The Calorizing Company.

Calorizing is a process whereby iron is driven into the surface of steel to form an iron-aluminum alloy. This alloy surface protects the steel against oxidation and sulphur corrosion up to maximum metal temperatures of 1650° F. The process is covered by General Electric Company patents under which The Calorizing Company, Pittsburgh, Pennsylvania, is sole commercial licensee.

Calorizing of earlier years was thin, brittle and poorly bonded to the base material with the result that it became detached under action of the tube expander and cleaner thus impairing the protection. The present day product, known as Heavy Duty Calorizing, is produced with a surface alloy ranging from 0.025 to 0.045 inch depth, well bonded to the steel. Tubes may be rolled in without injury to the seat and the tube expander has no injurious effect.

Calorizing is now applied to a number of low-priced, high-strength alloy steels presenting a tube which combines high temperature strength with oxidation and sulphur corrosion resistance to meet the requirements of many still operating conditions. Among the most promising of these are carbon-molybdenum steels containing 0.50 or 1.00 per cent molybdenum. They constitute an ideal base for calorizing and are free from tendency to air hardening or temper embrittlement.

ible to structural transformation at elevated temperatures, which alter the properties of the metal. Recent study of the behavior of steel at elevated temperatures has pointed the way to a better selection of metals for high temperatures service, or the heat treatment that will put the metal in the most useful and stable condition.[1-2]

STABILIZATION OF AUSTENITIC STEELS

The demand for steel for service above 900°F. has made necessary a more extensive study of the changes that occur in steels at elevated temperatures, as referred to above.

The 18-8 type of ferrous alloys has relatively high creep value combined with unusual resistance to certain kinds of corrosive attack and, therefore, fulfills the commercial requirements of certain high-temperature service better than any other metal now available. It is, therefore, important in connection with the application of this useful alloy that it be as stable as possible in service. It is true that cracking tubes made of 18-8 steel with the standard treatment have been used up to 1200°F. for two or three years without developing inter-granular attack, although the metal is subject to some inter-granular changes in this range that make it more susceptible to attack at the grain boundaries. It should be remembered, however, in considering this subject that this alloy is very resistant to many corrosive agencies, and that the severity of attack at the grain boundaries will be determined by the corrosive elements present, the period of exposure, and the temperature, as well as by the changes in the metal at the grain boundaries. It is fortunate that, as the temperature rises above 1300°F., chromium carbides precipitated at lower temperatures are re-absorbed—thus tending to provide increased resistance to the greater corrosive attack at higher temperatures.

The following statement in regard to the changes that occur at the grain boundaries in 18-8 within the approximate range of 900 to 1400°F. has been prepared by R. H. Aborn of the United States Steel Corporation Research Laboratory.[2]

"It is now well known that inter-crystalline corrosion may occur in austenitic chromium steels as a result of exposure of the metal to elevated temperatures. Susceptibility to this type of attack is believed to be induced somewhat as follows: Within the temperature range indicated, chromium-carbide, or a chromium-rich carbide, precipitates at the grain boundaries of the metal; the carbide particles probably contain as much as 90 per cent chromium. Their formation locally depletes the immediately adjacent metal of its chromium, so that along the grain boundaries it is too lean in this important element to resist attack unless the period of heating has been short enough, as in good welding practice with low-carbon alloys, to insure that no appreciable precipitation has occurred. If depletion does occur, prolonged heating at a sufficiently high temperature is required for diffusion of chromium in sufficient amount from the reservoirs within the grains to restore corrosion-resistance to the grain boundary regions.

"When such metal locally depleted in chromium is subjected to a severe corroding agent, attack proceeds along the grain boundaries, resulting in disintegration of the metal structure—although the grains themselves remain substantially unaffected. The severity of the effect is approximately proportional to the carbon content, owing to the fact that the phenomenon is a consequence of the localized precipitation of carbon from super-saturated solid solution. Alloys with carbon content under 0.07 per cent are comparatively free from this behavior, except perhaps after extremely long exposures. Reduction of the carbon content to the solubility limit (approximately 0.02 per cent at temperatures

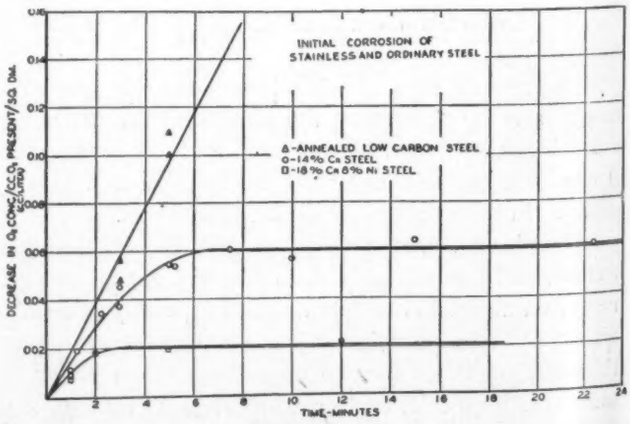

INITIAL CORROSION OF STAINLESS AND ORDINARY STEEL
Δ-ANNEALED LOW CARBON STEEL
O-14% Cr STEEL
□-18% Cr 8% Ni STEEL
DECREASE IN Cl_2 CONC./CC. Cl_2 PRESENT/SQ. DM. EXPOSED
TIME-MINUTES

FIGURE 3

Rate of Corrosion Compared with Time. Plain Carbon, 14 Per Cent Chromium, and 18-8 Chromium-Nickel. (Forrest, Roetheli, and Brown).

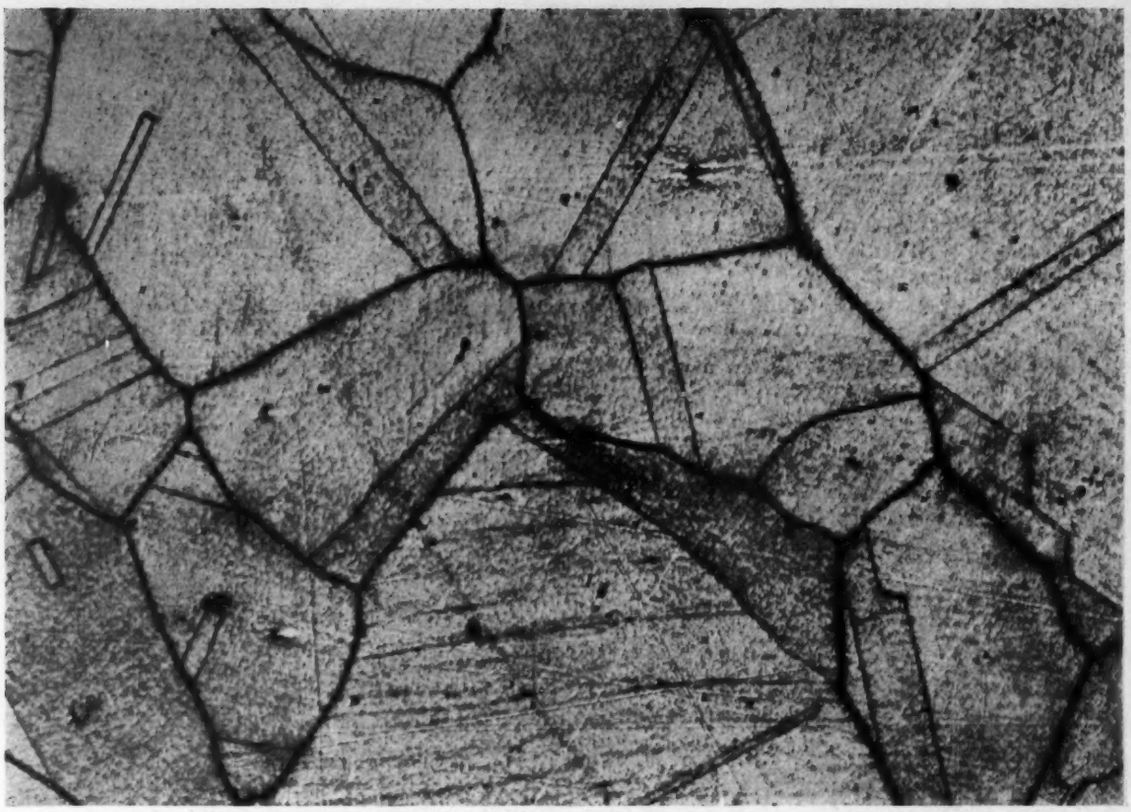


FIGURE 4
Photomicrograph (at 500×) of the Regular 18-8 Alloy in Which Carbides Have Precipitated at the Grain Boundaries.

below 1300°F.) would eliminate the effect altogether, but this course is impractical at present."

CREEP TESTING

Creep testing of the precision necessary for design purposes involves essentially: 1, uniform representative samples that will be structurally stable throughout the test period; 2, accurate loading, with stresses similar to those in service; 3, close control of temperature in the gage length of specimen; 4, precise measurement of temperature and strain; and, 5, to accurately indicate trend, creep tests should be continued for at least one or two years or approach the expected life of the material.

So far much of the creep data have been rather a test of testing methods. As little was known a few years ago regarding the essential factors, the results of these preliminary creep tests are naturally variable. Nevertheless, the data obtained afford a useful indication of the trend, if not always accurate enough as a basis for design of high-temperature equipment.

The Joint Research Committee of the American Society of Mechanical Engineers and the American Society for Testing Materials on "The Effect of Temperature Upon the Properties of Metal" has done much to center attention on this problem.

At the meeting of the American Petroleum Institute Refinery Standardization Committee in Houston last November, a sub-committee was appointed to act with technical representatives of manufacturers and the Joint Committee of American Society of Mechanical Engineers and American Society for Testing Materials to further the work of standardizing creep testing procedure. A special group representing these interests has been organized to consider this problem with respect to refinery materials. The immediate objective is to study the facts available, standardize methods of testing, and plan a series of tests on commercial ferrous alloys, using procedure that will give results reproducible within a reasonable range. This is an ideal problem for cooperative work.

TREND IN DEVELOPMENT OF FERROUS ALLOYS

It has been well said that we are now approaching, if not living in, the "age of alloy steel." Thousands of tons of the stainless and heat-resisting alloy steels are produced annually, and the demand for them is increasing. Notwithstanding the considerable advances which have been made in the manufacture of these steels—with respect to quality and a knowledge of their properties at elevated temperatures—additional data must be developed through individual and cooperative work to complete the picture.

The trend toward use of alloy steels will, generally speaking, be determined by the ultimate cost of protection over a period of years or the expected life of the unit. The main factors which determine or direct this trend are: original cost of material, durability, reliability, cost of replacement (including loss of production), and incidental damages that may result from

TABLE I

COMPOSITION	ALLOY TYPE					
	5	12	17	27	18-8	25-12
Chromium (per cent)	4-6	12-14	16-18	25-30	16-20	22-28
Nickel (per cent)	.....	.....	.....	.....	8-12	12-16
Manganese (per cent) (maximum)	0.50	0.50	0.50	0.50	0.50	.....
Silicon (per cent) (maximum)	0.50	0.50	0.50	0.50	0.50	.....
Carbon (per cent) (maximum)	0.15 or 0.20	0.10	0.10	0.10	0.15	0.25

failure. The last may be practically eliminated by careful periodic inspection, calipering the metal, and/or by the use of small sentry holes drilled partly through the metal so as to give timely warning of serious reduction in wall thickness.

Commercial ferrous alloys of various chromium and chromium-nickel content, with tungsten, molybdenum, titanium, and other useful additions, have been developed for use under corrosive conditions. The alloys most generally used for such purposes may be divided into a few types according to the chromium contents as listed in Table 1.

These types have several modifications, most of which have not yet been fully established in commercial use.

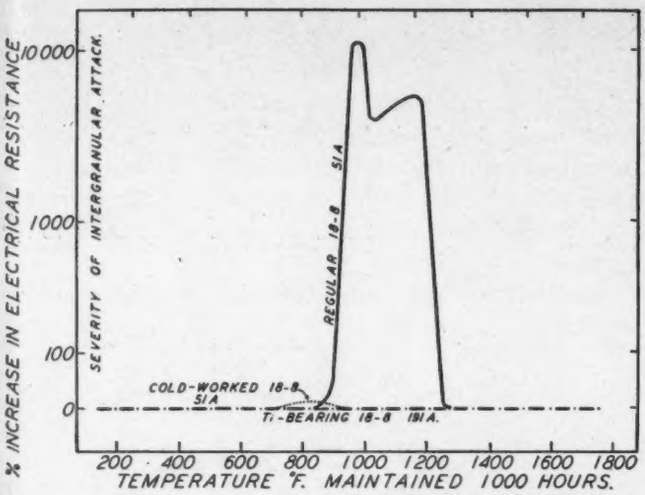
With reference to the low chromium series, the following conclusions have been drawn from recent tests in the Research Laboratory, National Tube Company, on steels with from one to seven per cent chromium.[8]

"The results of this investigation indicate that steels of desirable properties may be obtained from the range of composition and heat treatments studied. It is evident that the one per cent chromium series does not contain sufficient chromium to improve either the mechanical properties or corrosion resistance to any marked extent, while the steels containing seven per cent chromium do not exhibit any particular advantages over those containing three and five per cent chromium.

"Physical properties of the three and five per cent chromium alloys developed some interesting possibilities. In the first place, these steels can be soft-annealed to develop properties very similar to those of mild carbon steels, and therefore suitable for equipment where severe cold work is applied during fabrication. On the other hand, some steels with remarkably high yield points and tensile strengths, combined with excellent ductility and impact toughness, can be produced by simple air-hardening treatments. It is obvious that many articles of shapes that make quenching in liquid media difficult might be produced from steels containing either three or five per cent chromium, and subsequently heat-treated, without excessive distortion, to desired prop-

FIGURE 5

Photomicrograph (at 500×) of the Improved Alloy in Which Carbides Have Precipitated Substantially Throughout the Grains.



Relative Susceptibility to Inter-granular Attack of 18-8 Alloy: a, Ordinary; b, After Cold Work and Heat Treatment; c, Containing Titanium, After 1,000 Hours' Exposure to the Temperature Indicated Followed by a Very Severe Corrosive Attack in a Controlled Acid Medium, as Measured by an Electrical-Resistance Method. The Rate of Attack in Service Depends Upon the Conditions of Exposure, and May Not Be Appreciable Even When the Alloy Has Become Susceptible.

erties. A noticeable feature of these air-hardening alloys is the variation in the elastic ratio; for example, these steels in the air-hardened and untempered condition have ratios of yield point to tensile strength of about 0.50 to 0.55, and even lower proportions in the fully soft-annealed condition. Reheating of the air-hardened steels to various tempering temperatures reduces the tensile strength noticeably, while the yield point is only slightly lowered and elastic ratios of about 0.75 and 0.80 appear in the tempered specimens.

"It is believed that the particular properties exhibited by these alloys, as compared to ordinary air-hardening steels, can be associated with their structures. Most of the S.A.E. steels that show air-hardening properties also have a pearlitic structure when soft-annealed. On the other hand, the structures of the three and five per cent chromium alloys rarely exhibit normal pearlite, the carbides usually being of a globular or coalesced type dispersed throughout the ferrite matrix. It is believed that on hardening and tempering this tendency toward random dispersion of carbides promotes the high tensile properties and also the high impact toughness which pearlitic steels do not develop."

The relative corrosion resistance of some of these steels under different conditions of exposure is indicated in Figures 4 and 5. The physical properties of four to six per cent chromium steels showing the effect of carbon content and heat treatment are given in Table II.[1]

The protective influence of chromium usually shows a marked increase at 11.5 per cent. The stainless steel alloys, indicated above as the 12 per cent chromium type, respond readily to air hardening and may, therefore, be obtained with a wide range of phyical properties. They resist oxidation quite well up to about 1500°F. This type, however, is not so suitable for fabrication into seamless pipe as the 17 per cent chromium or 18-8 type referred to below.

The 17 per cent chromium steel resists oxidation continuously at temperatures up to 1550°F. In the annealed condition it is ductile and malleable, and is suitable for cold working—except for the most severe forming operations, in which case the 18-8 type is preferable. The 17 per cent chromium alloy is available in the form of bars, shapes, strips, sheets, plate, tubes, and wire. It is preferable to the 12 per cent chromium alloy for resistance to oxidation and corrosion at high temperatures, but is not suitable for cracking tubes. Furthermore, in some forms the alloy is almost as costly as the 18-8 type, but the 18-8 in many instances is easier and safer to weld.

The 27 per cent chromium type is used principally for resistance to oxidation at temperatures between 1500 and 2100°F., and may be obtained in the form of sheets, plates, rounds, flats, bars, and tubing. It is not suitable for cracking tubes.

Both the 17 and 27 per cent chromium types show brittleness at room temperature when cooled slowly from temperatures between 800 and 1100°F., although they are not brittle at above 500 or 600°F. This char-

TABLE II

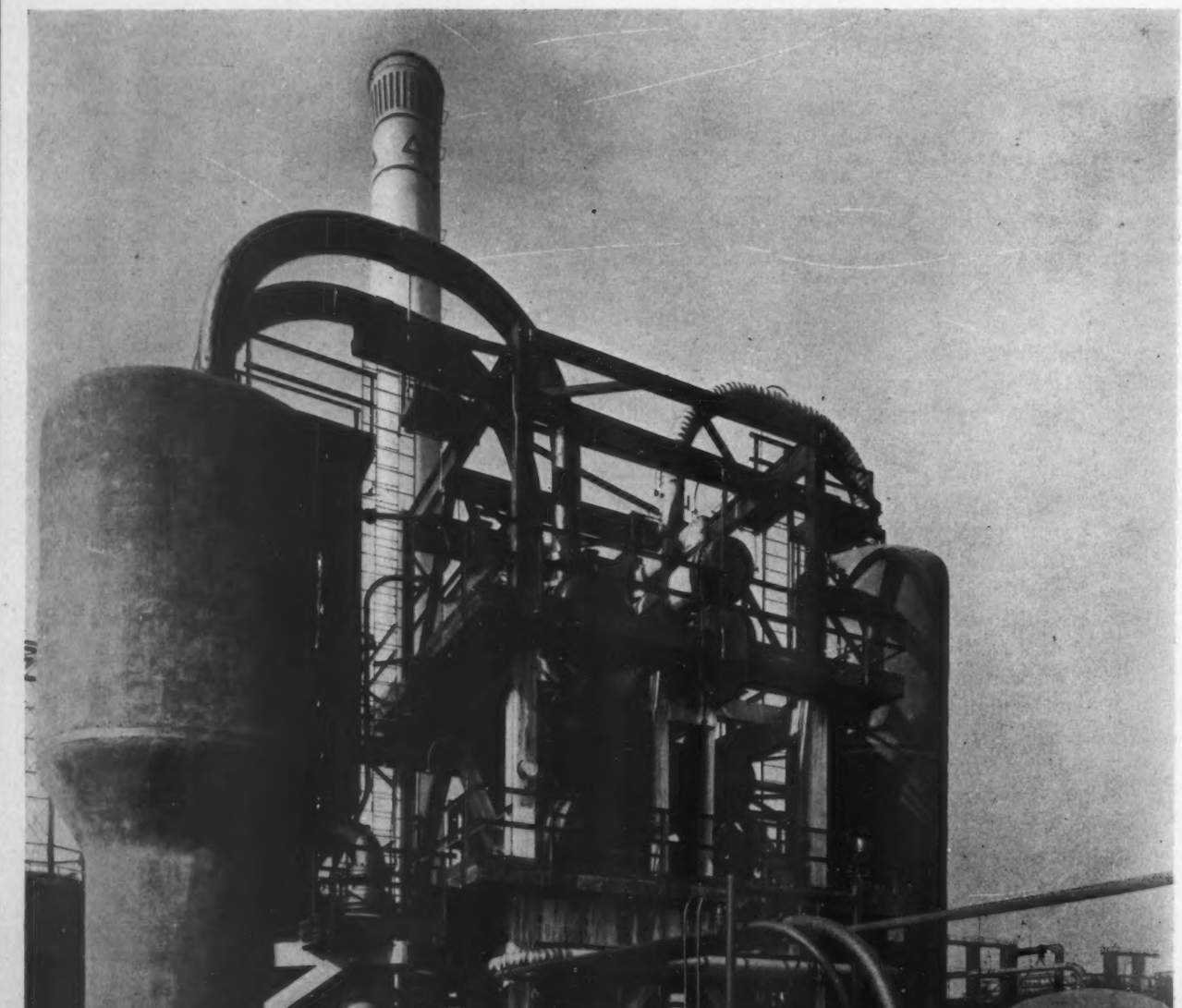
Physical Properties 4-6% Chromium Steels, Showing Effect of Carbon Content and Heat Treatment

Carbon	Chromium	Air Cool	Draw	Yield Point	Tensile Strength	%—2 in. elong.	R. A.	Brinell	Izod.
.10	5.20	875°C. 1,600°F.	None	108,860	181,420	15.5	53.2	361	23.0
.20	5.20	860°C. 1,575°F.	None	114,000	212,310	9.0	18.5	417	23.0
.30	5.30	860°C. 1,575°F.	None	118,200	222,100	13.5	31.7	448	16.9
.10	5.20	875°C. 1,600°F.	600°C. 1,110°F.	102,180	114,100	20.0	71.0	250	76.4
.20	5.20	860°C. 1,575°F.	600°C. 1,110°F.	120,100	137,600	18.5	58.7	272	36.0
.30	5.30	860°C. 1,575°F.	600°C. 1,110°F.	116,840	137,400	18.0	60.5	275	59.1
.10	5.20	875°C. 1,600°F.	Furnace Cooled	27,300	62,030	37.5	75.6	136	84.2
.20	5.20	860°C. 1,575°F.	Furnace Cooled	33,200	75,600	32.0	75.0	152	84.1
.30	5.20	860°C. 1,575°F.	Furnace Cooled	34,600	79,200	31.5	73.6	161	79.3

acteristic limits their use at elevated temperatures to low-pressure work.

The 18-8 chromium-nickel series of stainless steels has a wide application, due to the useful combination of desirable physical properties and wide range of resistance to corrosion attack. While the 18-8 metal was not developed primarily for high-temperature service, it has come into this field to a considerable extent on account of its high creep value combined with unusual resistance to oxidation and corrosion. The coefficient of expansion of this alloy is about 1½ times that of low-carbon steel, whereas the 12 and 17 per cent chromium steels have a coefficient about the same as that of carbon steel. It is very fortunate that such a metal is available combining desirable physical properties with ease of fabrication and good welding quality. The use of this alloy has increased considerably during the past two years, so that the higher initial cost seems in many cases to be justified by experience.

The 25-12 per cent chromium-nickel steel represents



Modern two-stage atmospheric-vacuum pressure distillate redistillation unit, 9,000 barrels daily capacity, in a large Eastern refinery, erected by E. B. Badger & Sons Company.

a further improvement in heat-resisting alloys, and is primarily intended for resistance to oxidation at temperatures up to 2100°F. At the same time, it retains a large portion of its strength and toughness through this range of temperature. This alloy is obtainable in the form of plates, sheets, rods, flats, and bars. Other alloys containing still higher chromium or nickel contents with other elements, such as molybdenum and tungsten, have been developed for special service, but the above include the principal types now commerically used.

In the case of cracking tubes, experience indicates that ordinary 0.10-0.20 carbon tubes have been used economically in some cases up to as high as 1200°F. tube wall temperature where sulfur-corrosion is practically absent. For similar tube temperatures, four to six per cent chromium steels (with or without 0.5 per cent molybdenum or one per cent tungsten) have been used where a moderate amount of sulfur-corrosion is encountered. The molybdenum or tungsten alloys seem to have a somewhat higher creep value. With highly corrosive oils, 18-8 steel has been used to advantage, especially for the higher temperature parts of such installations as are likely to be in service for a long period. The present trend in high-pressure liquid phase cracking, however, is decidedly toward the use of the four to six per cent type of chromium steels where sufficient corrosion-resistance is not obtainable with carbon steel.

The use of four to six per cent chromium tubing has been gaining at the expense of carbon steels during the past two years, for the good reason that experience shows that this alloy generally lasts four to 10 times as long as carbon steel in cracking-tube installations handling high-sulfur crude oils. The former is about three times as costly as the latter. This radical change by consumers is based on four or five years' experience in service and may, therefore, be considered significant of a definite trend—expressive of a wise conservatism and compromise. When properly annealed, the four to six per cent chromium alloys have physical properties at ordinary temperatures comparable to plain carbon steels, and yet are stronger and sufficiently more resistant to corrosion at moderately high temperatures to warrant, as a rule, the increased cost over plain carbon steel.

The improvements made in 18-8 referred to above, in discussing "stabilization," have tended better to adapt this alloy to use at higher temperatures and pressures. In some cases the regular 18-8 tubes have been taken out for inspection and re-heat-treatment after two years' service without exhibiting material inter-granular corrosion or deterioration. When the requirements of the refinery industry for material for temperatures above 1000°F. at high pressures have been more definitely established, these metals may be modified to meet the conditions anticipated. Standard specifications for five per cent chromium still tubes are now being prepared by representatives of the A.P.I. and manufacturers working with the A.S.T.M.

SUMMARY

With reference to the important metallurgical factors affecting trend in choice of metals for high-temperature service, it is recognized that more reliable data are required by the designing engineer as to the effect of elevated temperatures on the physical properties and structure of these metals. More rapid progress in this work may be expected by closer cooperation between consumers and producers, especially in the work of standardizing procedure in creep testing and in carrying out durability tests under representative conditions in service. Standardization of specifications for alloy steels by joint action of the consumers and producers is also highly desirable. The present apparent trend is decidedly towards the wider use of alloy steels, especially of the five per cent chromium type, when dealing with corrosive crude oil. Carbon steel, however, is still most generally used. Tungsten (one per cent) or molybdenum (0.5 per cent) added to either of the above gives a moderate increase in resistance to creep, but the actual value of these additions has not yet been definitely determined in general practice.

The regular 18-8 chromium-nickel alloy is reported to have justified the higher initial expense in certain cracking-tube installations, but very few of these alloy tubes have been installed during the past year.

The cause of inter-granular corrosion occasionally found in this alloy is now fairly well understood, and two modifications of the 18-8 are available that promise to render this important alloy acceptable for temperature service up to 1300 or 1400°F. A very considerable increase in use of the 18-8 alloy for other purposes at lower temperatures has developed during the past year or two.

In the last analysis the experience of consumers determines the trend of development by selecting the most economical material for the purpose. It would, therefore, be helpful to manufacturers in particular to have a full discussion of this paper from the standpoint of large consuming interests.

RECENT BIBLIOGRAPHY

[1] E. C. Wright, "Selection of Ferrous Metals Used in Refineries Has Developed to Paramount Importance," *Oil Gas J.* vol. 31, no. 20, 57 (1932).

[2] F. N. Speller, "Development and Trend in Ferrous Alloys for High-Temperature Service," Proc. Amer. Pet. Inst., November 15, 1932.

[3] E. C. Wright and P. F. Mumuma, "Properties of Low-Carbon Medium-Chromium Steels of the Air-Hardening Type," Tech. Pub. No. 496-C-94, A.I.M.&M.E., February, 1933.

[4] J. J. B. Rutherford and R. H. Aborn, *Trans. Am. Inst. Mining Met. Eng.* (Iron and Steel Div.), 100, 293 (1932).

[5] H. D. Newell, "The 18-8 Iron-Chromium-Nickel Alloy with Particular Reference to Its Characteristics for Cracking Coil Service." *Proc., First Mid-Year Meeting, Div. of Ref., Amer. Pet. Inst.*, p. 28 (Apr. 1931).

[6] J. H. G. Monypenny, *Stainless Iron and Steel*, John Wiley & Sons, Inc., New York, p. 285-9 (1931).

[7] P. Payson, "Prevention of Inter-Granular Corrosion in Corrosion-resistant Chromium-Nickel Steels," *Am. Inst. Mining Met. Eng. Tech. Publication No. 464* (Feb. 1932).

[8] J. J. B. Rutherford and R. H. Aborn, "A Quantitative Method for the Estimation of Inter-crystalline Corrosion in Austenitic Stainless Steels," *Am. Inst. Mining Met. Eng.* (Feb. 1932).

[9] E. C. Bain, "Some Fundamental Characteristics of Stainless Steels," *J. Soc. Chem. Ind.*, 51, 662-6, 683-90 (Aug. 5 and 12, 1932).

[10] R. J. Allen and F. B. Applegate, "Many Types of Materials Available for Use in Manufacture of Equipment for Oil Industry," *Oil Gas J.*, vol. 31, no. 21, 12-3, 30 (Oct. 1932).

[11] V. T. Malcolm, "The Selection of Materials for High Pressure and High Temperature Work in Oil Refineries," *Oil Gas J.*, vol. 31, no. 21, 14-6 (Oct. 1932).

[12] J. H. Critchett, "Stainless Steels and Irons," *J. Am. Welding Soc.*, 11, 32-4 (Nov. 1932).

[13] C. A. Scharschu, "Stainless Steel," *J. Am. Welding Soc.*, 11, 34-6 (Nov. 1932).

A more extensive bibliography will be found in (2).

Alloy Steels . . .
for Petroleum Refining Equipment

THE accompanying article which deals with alloy steels for equipment used in the refining of petroleum presents much information of interest and value dealing with the various alloys, their manufacture, fabrication, and utilization information and of a type not generally included in articles prepared for the refining industry. This work was done under the direction of E. C. Smith, chief metallurgist, Republic Steel Corporation, who contributed a portion of the article. Another part of the article was contributed by C. C. Snyder, Sales Department, Republic Steel Corporation. E. R. Johnson, Assistant Chief Metallurgist, Central-Alloy Division of the same company contributed the section dealing with metallurgy of production of the alloys. V. W. Whitmer, Metallurgical Engineer, Central-Alloy Division for Republic Steel Corporation, who services the fabrication of such materials in the field, contributed the section on fabrication.

METALLURGICAL SYMPOSIUM

A NUMBER of factors have been responsible for the introduction of alloy steels into the oil refining industry. It will not be attempted here to enumerate their order of importance, as such a classification would be subject to much argument. Suffice it to say that the demand for high powered gasolines has caused the refiner to resort to higher operating temperatures and pressures, with resultant increase in corrosion problems, and demand for higher strength materials. Sulphur contents of crude oils range from the very low, .05 to .10, in Pennsylvania oils, to the 2.0 to 3.5 per cent of the Texas and California crudes. The high sulphur content crudes are quite corrosive; the higher the operating temperatures, the more corrosive are these crudes and their effects on common steel.

Carbon steel loses its strength rapidly at elevated temperature. Likewise, it scales readily, and thus decreases in section, causing further loss in strength. In the case of carbon steel cracking still tubes, frequent replacements were required, resulting in a high maintenance cost, as well as the loss of the use of equipment during repair periods. In order to combat these corrosion and scaling problems, and to obtain steels having higher creep strengths at elevated temperatures, it was necessary to resort to alloy steels of the high chromium or chromium-nickel type. It is believed that the first alloy steel used for cracking coil tubes was the 16.5 to 18.5 per cent straight chrome low carbon alloy. The use of this alloy for the above service was very limited, because of its tendency toward embrittlement after exposure at temperatures of approximately 900 to 1025° F. When this characteristic became known, the alloy was withdrawn from such service. At about this time, 1928, the 18-8 type alloy (18 per cent chromium-8 per cent nickel) began to see service. Eighteen-eight had even better corrosion resistance properties than the straight 18 per cent chromium alloy, had better creep strength at elevated temperatures and was not subject to the same embrittling tendency as the latter.

Figure I is a chart showing relative scaling resistance of alloy steels, ranging from 4-6 per cent chromium alloy to the 25.0 per cent chromium-20 per cent nickel of the NC-3 alloy suitable for oil refinery equipment.

Regardless of all the sterling qualities a certain material has, usually a detrimental characteristic makes its appearance which augurs against its complete adoption.

Such was the case with 18-8, when it was discovered that, unlike carbon steel tubes, 18-8 tubes did not bulge previous to failure, and hence gave no warning of approaching danger. The question naturally asked here is —why did 18-8 tubes fail if they were of such high strength and unaffected by corrosion. The answer is just as natural—if a tube is designed for a certain pressure at a certain temperature and this pressure is increased or the tube temperature raised three or four hundred degrees, failure must be expected. That is exactly what happened with probably 20 at the most 18-8 cracking coil tubes. There were, and still are, thousands of these tubes in service, and, where operating conditions were kept within reason, wonderful results have been obtained from 18-8. It is probably but

natural for the refiner, who is buying a high priced alloy tube, to push it pretty hard in order to derive maximum benefits. It has been in such cases that failures have occurred. Now that the characteristics of 18-8 are generally known, there should be no excuse for failures due to overheating.

The jump from a carbon steel tube to an 18-8 alloy tube was an enormous one, and to some refiners the great increase in initial cost did not appear to be justified. Too, conditions found in some refineries, while fatal to carbon steel, were not severe enough to warrant the use of 18-8. This state of affairs brought about the introduction of the 4-6 per cent chromium alloy. When it was found that the 4-6 per cent chromium alloy had embrittling tendencies, similiar to the 16.0-18.0 per cent chromium alloy, small quantities of molybdenum (.40-.60) were added, which overcame this detrimental property, and also added to its creep values. Tungsten contents of 1.00 to 1.25 per cent have likewise been added, for greater creep strength. Several thousand tons of tubing of the 4-6 per cent chromium analysis, with and without other alloy additions, are in service. While the cost of 4-6 per cent is several times more than for carbon steel, it is much less than for 18-8. True, it does not have the same degree of corrosion resistance as 18-8, nor as high creep strength, but it does have the properties, at a reasonable price, in which the refiner is interested today. It has been reported to be giving from four to ten times the life of carbon steel tubes under similar conditions.

An eastern refiner has proven himself very versatile in the selection of tubes in the cracking coil. In the hottest zones are found 18-8, then 4-6 per cent chromium with molybdenum, and then finally, in the coldest zones, are carbon steel tubes. The embodiment of three types of tubing on one coil is perhaps an innovation, but, from the results obtained, has proven itself a valuable one, and one which other refiners would find well worth following.

To obtain the best service from alloy tubing return bends should be of the same composition. These can be obtained in 4-6 per cent chromium and 18-8, in either cast or forged form.

High content chromium and nickel alloys are used for tube supports, as well as for tube sheets, and other heat resistant furnace parts. Soaking drums and reaction chambers have been lined with 18-8 material, the sheets being spot welded to the common steel base. Such

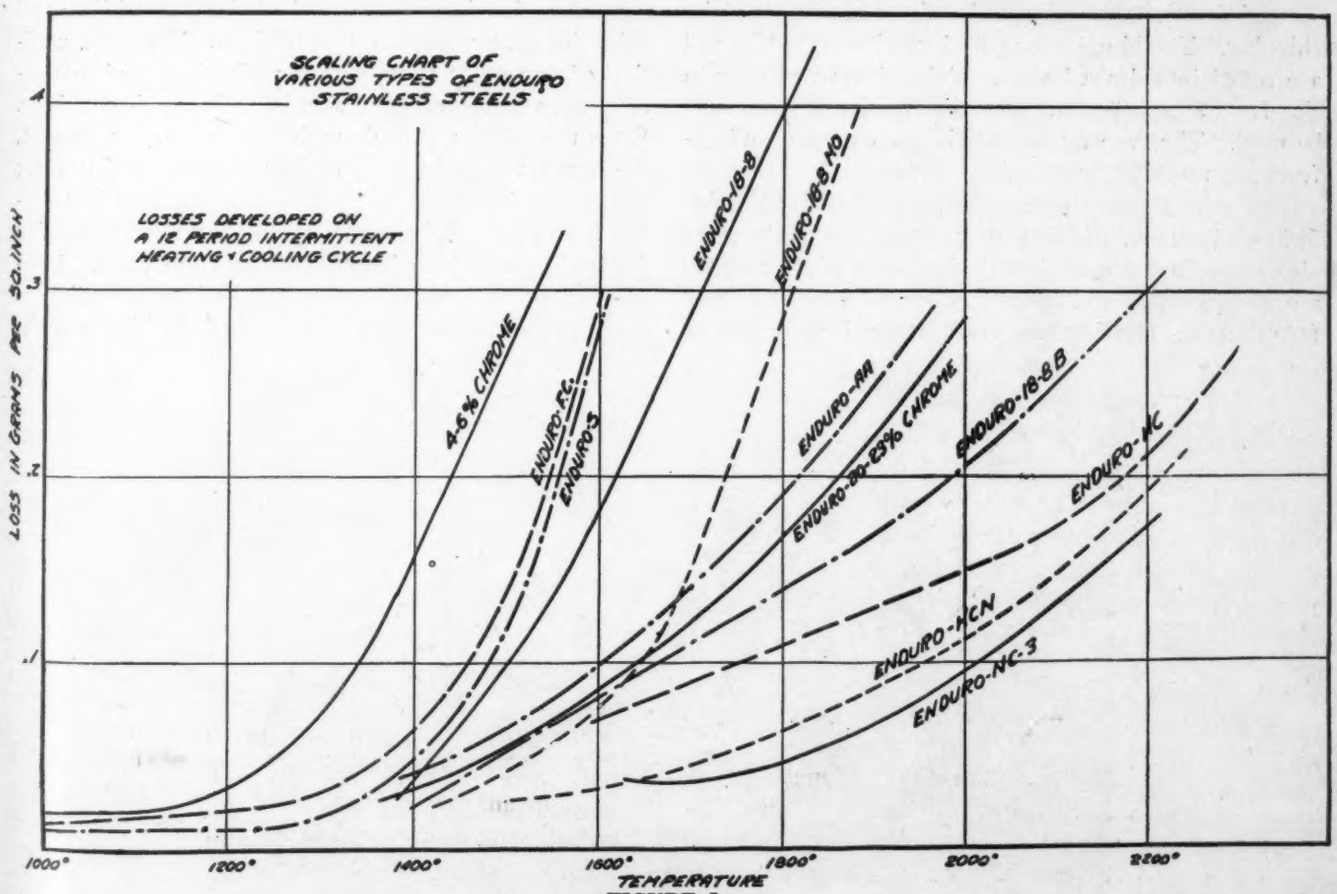


FIGURE 1

Type of Alloy	*Alloy Content*
4-6% Chromium	4.00- 6.00% Chromium
ENDURO S-FC	12.00-15.00% Chromium
ENDURO 18-8	18.00% Chromium, 8% Nickel
ENDURO 18-8-MO	20.00% Chromium, 9% Nickel, 3% Molybdenum
ENDURO AA	16.00-18.00% Chromium
ENDURO 20-23	20.00-23.00% Chromium
ENDURO 18-8-B	18.00% Chromium, 8% Nickel, 2.5% Silicon
ENDURO HC	25.00-30.00% Chromium
ENDURO HCN	25.00% Chromium, 12% Nickel
ENDURO NC-3	25.00% Chromium, 20.00% Nickel

construction embodies the superior corrosion resistance of 18-8 with but a small portion of the cost of solid 18-8 involved.

Still plugs, bubble caps, vapor lines, hot oil lines, pump parts, valve bodies and fittings, impellers, oil preheaters and heat exchangers have been found to be ideal applications for alloy steels.

A recently reported application for 4-6 per cent chromium with molybdenum has been for condenser tubing. Because of the high sulphur content of the crudes being run, 4-6 per cent chromium should prove adaptable. Eighteen-eight has seen some service for condenser tubing, but generally its record is unsatisfactory. This is perhaps because of its high coefficient of expansion, which causes the metal, when held fast, to work harden and fail, due to a combination of corrosion and fatigue. The presence of hydrochloric acid will likewise cause failure. Several test units of 18 per cent chrome, possessing a low coefficient of expansion, are reported to have given a satisfactory record.

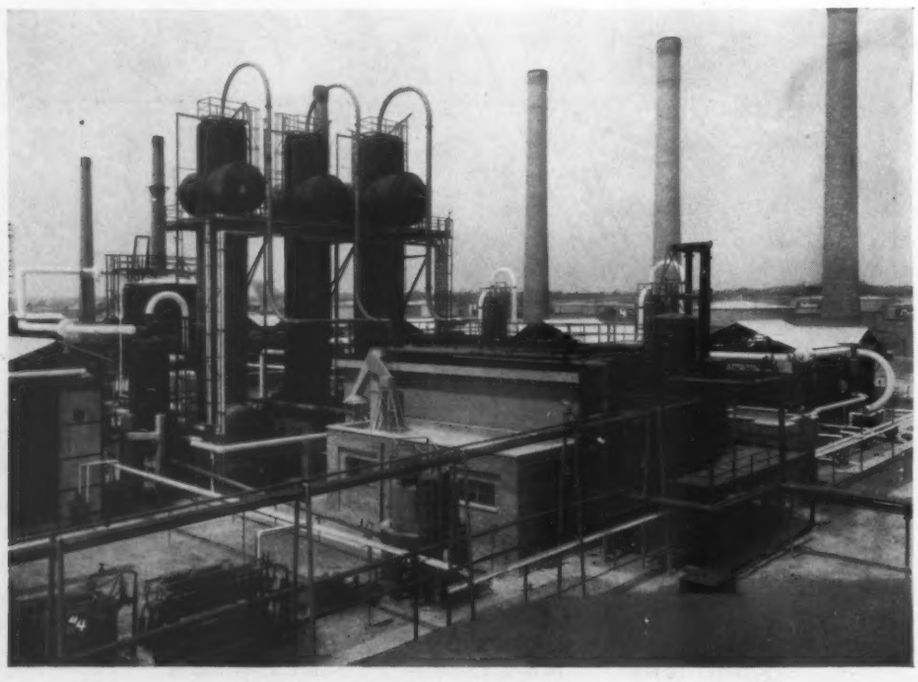
Manufacture

THE plain carbon analyses of varying carbon content are made in the open hearth furnace of approximately 75 to 100 tons capacity. In some cases, the steel is not killed and is allowed to rim during solidification in the ingot. Tubing made from this material will have maximum softness for any necessary fabrication. The same analysis for still tubes, .10/.20 carbon, is also killed with silicon and aluminum, which produces a uniform sound product.

The ingots are heated to temperatures of approximately 2250-2300° F., rolled to billets, which are inspected for defects. Harmful defects are removed by chipping. The billets are again heated to 2250° F. and are rolled into desired sizes. Tube billets will vary in size from 3 to 5½-inch. Occasionally, larger sizes may be used. The tube rounds are inspected again and defects are removed by chipping.

The general alloy steels, such as SAE 3140, SAE 5140 and others, which may be used for bolting, are also made in the open hearth furnaces. Such analyses are always killed and careful attention is given to surface defects. Heating temperatures on the mill will be approximately 100 degrees lower. Since most bolting material is furnished to physical specifications, the bars are quenched and drawn, using treatments to meet the requirements.

The semi-heat resisting and full stainless analyses, such as 4-6 per cent chrome group, which may contain tungsten or molybdenum, and the 18.0 per cent chrome-8.0 per cent nickel, .07 max. carbon, are made in the electric furnaces, either arc or induction. Heroult arc furnaces are generally used with varying capacities up to 30 tons. A conventional practice consists of melting a good grade of scrap, removal of slag, use of lime and silica for a new one, addition of ferro chromium, addition of any other alloy, addition of silicon and manganese, tests for temperatures and finally tapping of heat. Since the alloys are made with varying carbon content, the best grade of ferro chromium must be used to meet the desired carbon range. Naturally, the very low carbon alloys make it imperative to use the most expensive ferro chrome, which increases production costs. Usually the ferro chrome charge is split into several portions, preheated and then added, which facilitates melt-



Gyro vapor phase cracking units at Pure Oil Company's Marcus Hook, Pennsylvania Refinery.

ing time and prevents too much chilling of bath and slag.

There are several types of induction furnaces—high frequency and low frequency. The high frequency furnace consists of a crucible surrounded by a copper coil which carries current of high cyclic charge. This produces a magnetic field which causes the generation of heat due to the resistance offered by the steel charge to the flow of current. The scrap is melted and alloy additions are made until the desired analysis is obtained. In this process, there is a constant motion of metal so that it is difficult to retrain protective slags. One unit of fairly high frequency with four tons capacity has a satisfactory operating history.

The other type of induction furnace operates with low frequency. In this case, the scrap charge is placed in a circular hearth surrounding a laminated sheet core connected to outside cores. These laminated sections carry the magnetic circuits produced by a circular copper ring. This ring is considered the primary, while the charge becomes the secondary and is heated because of the resistance offered to the flow of current. Here again scrap is melted and the necessary alloys are added to bring the melt to the required specification. One unit of low frequency with six tons capacity has a satisfactory operating history.

Both types of induction furnaces serve an admirable purpose by helping to utilize the stainless scrap. There is very little loss of chrome content during the melting operation, so that practically all alloy content is recovered. It thus becomes possible to remelt, make small additions of silicon and manganese to build up to required analysis, and pour again into ingot form.

The liquid metal tapped from any of the above furnaces is teemed into moulds of many sizes. Typical ones are 8 x 8, 10 x 10, 13 x 16, 17 x 20-20-inch Rd. varying in weight from 550 to 4750 pounds. The simple analyses are cast into the larger ones, while complex and heat resisting alloys are usually poured in smaller moulds to facilitate subsequent hot working operations. The alloys of 16-8 chrome and 18 per cent chrome-8 per cent nickel have been cast into much larger moulds weighing 20,000 to 60,000 pounds.

The semi-heat resisting and simple stainless alloys are rolled on blooming mills to billets and slabs. The full stainless alloys, such as a 25.0 per cent chrome-20.0 per cent nickel alloy, are forged, as the working ranges are narrow and frequent reheating is necessary to obtain reductions and prevent bad cracking. Soaking pit temperatures for rolling vary from 2150 to 2300° F., while forging temperatures are lower, 2050 to 2200° F. The 4-6 per cent chrome group and the 18 chrome-8 nickel—.07 max. carbon, belong to the first series.

The billets for tube rounds of 4-6 per cent chrome group are carefully cooled to protect quality, while the 18-8 billets are air cooled. All billet surfaces are carefully chipped and ground to remove surface defects. The prepared billets are then reheated to temperatures of 2200 to 2250°F. and rolled to rounds of various sizes. The 4-6 per cent chrome group are pickled and either chipped or ground to remove any remaining surface defects. The 18-8 analysis is completely turned to obtain a surface entirely free of defects.

The slabs produced from the ingots are likewise thoroughly cleaned to remove all surface imperfections. Some slabs go to the sheet mill where they are heated and rolled on a jobbing mill to sheet bar. The sheet bar is again reheated in a conventional air heating furnace to temperatures depending entirely upon the analysis of the alloy, low 1500° F. for straight chromes, high 1850° F. for chrome nickels. Sheets are rolled from the sheet bar, observing precautions relative to draft on the mill. These sheets are annealed at specific temperatures—1450 to 1500° F. straight chromes and 1900 to 1950° F. chrome nickels, followed by pickling in special acids of (1) 10 per cent H_2SO_4 plus 8 per cent HCl (2) 10-15 per cent HCl (3) 10 per cent HNO_3 — 1 per cent H_2F_2 (4) 25 per cent HNO_3—using 1, 2 and 3 for straight chromes and 1, 3 and 4 for chrome nickels. After this preparation, the sheets can be cold rolled severely to obtain good surface and then re-anneal and pickled for softness for deep drawing. The wider sheets are merely cold rolled and patent leveled if required after the first anneal. Some of the sheets are sent to the polishing department where many special finishes are produced, ranging from a matte appearance to mirror reflectiveness.

Other slabs are rolled on the strip mill into coils of strip .090-.195 thick. These coils are annealed and pickled, as mentioned before, cold rolled on a tandem four-high mill (three stands) with 50-60 per cent reduction, re-annealed and pickled continuously, again cold rolled, until finally after repeated processing, the finished strip is obtained with a uniform pickle finish.

PIERCING MILLS

The tube rounds are pierced in mills having different types of piercing and rolling equipment. The tube rounds are heated to piercing temperature in furnaces which are inclined to permit continuous rolling of the billets from the cold end of the furnace to the hot zone. The heating times and temperatures are dependent upon the type of equipment and upon analysis ranging from 2200 to 2300°F. The heated rounds pass through the piercing rolls, either Mannesman type or Steifel discs, which rapidly reduce the diameter of the round and then cause the metal to flow over a point, thus producing a pierced hollow. The setting of the rolls will control the wall thickness, while the guides will control the outside diameter. The pierced hollow then passes through a two-high mill, using a plug on the inside. This operation reduces size and wall thickness and eliminates the piercing mill marks. The rolled tube is then given a pass through another set of rolls, which rapidly revolves the tube and makes the outside diameter uniform. The tubes may be reheated and sent through a series of rolls, which reduces the outside diameter, or the tubes

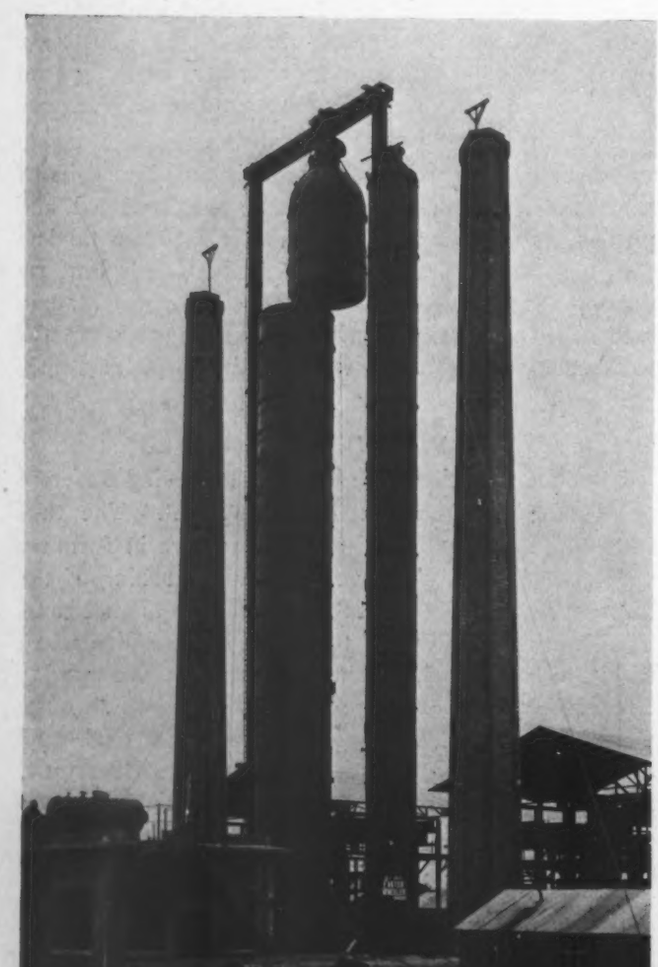
may go directly through a series of rolls for sizing pass to make the outside diameter still more uniform.

The carbon steel tubes of low carbon content will be soft coming from the hot mill and can be easily fabricated. The alloy tubes of 4-6 per cent chrome series will require an annealing treatment to make them soft. Usually this annealing temperature is 1525 to 1575° F., cooling slow enough to get desired hardness under 179 Brinell. Scale can either be removed by pickling or sand blasting. The 18-8 analysis is usually annealed at about 1850 to 1950° F. and quenched in water to produce a small uniform austenitic grain structure.

Condenser tubing will be cold drawn from the annealed and pickled material. Since the sizes are small, a number of cold drawing passes are necessary so that intermediate annealing and pickling is required between drafts. The annealing temperatures will be low for the plain chrome series (4-6 per cent chrome group and 16-18 per cent chrome.)

Fabrication

IN the production of various equipment, steel has played an important part, probably due to its ease of fabrication. Pressure vessels, tubes, tube sheets and such are readily formed, flanged, dished, etc., either hot or cold, depending on their thickness. In recent years, welding has probably been the most important single improvement in steel plate fabrication. Today many castings are being replaced with welded plates and shapes, and the physical properties of the weld are frequently equal to or better than the base metal itself.



Port Jerome, France, refinery of Vacuum Oil Company, S. A. F., showing top section of vacuum tower about to be placed into position on a Foster Wheeler unit.

Alloy steels of the low alloy content such as the S.A.E. types, have not generally been used in such construction as they have in the automotive and similar fields. The change from boiler or firebox plate was due primarily to the necessity of meeting greater corrosion resistance or physical strength at high temperature which usually required the higher alloy type.

The chrome nickel iron alloys, being austenitic in structure, possess great ductility and hence lend themselves well to various type of fabricating. The tensile strength is about 50 per cent more than that of ordinary boiler or firebox steel and will, therefore, require more power in rolling or forming operations as will any stiffer material. However, in many cases this very property, which may at first be objectionable in working, frequently turns out to be an asset in the finished product, due to greater stiffness or rigidity. They can be forged, rolled, drawn, welded or riveted into most any shape desired. The straight chromes, while possessing less ductility, can, under proper conditions, also be worked into most any product required.

FORGING AND FLANGING

In forging these chrome-nickel alloys, they should be heated slowly to about 1500°F. and then rapidly to 1900-2200°F., which is the best forging range. If the job cools to 1700°F. before finishing, such as in large sections, it should be reheated. No hot work should be done between 1200 and 1700°F., as the alloy is hot short in this range and any work is likely to produce cracks or check, which may lead to fatigue failures after going into service. This same applies to any hot working, such as dishing, spinning or flanging heavy heads or shapes, bending tubes, driving rivets, etc.

The 4-6 and 14 and 17 per cent straight chrome alloys should not be heated any higher than necessary to flow the metal for the job at hand, and should always be finished at a low temperature, around 1300-1400°F. Heavy forging can be started at 2100°F. but flanging, riveting, bending, etc., should be done between 1300-1400°F. to prevent grain growth which occurs with high finishing temperatures. This temperature control is especially important with 17 per cent chrome as this alloy does not respond to heat treatment. The 4-6 per cent chrome product can be heat treated after forging, but low finishing temperatures are advisable. All rivet-

ing should be done below 1350°F. to prevent air hardening on cooling.

ROLLING

There will be a tendency for rolled sections such as shells, to offer more spring back than ordinary steel, due to the work hardening taking place in the metal in the successive reductions. It will, therefore, be necessary to apparently roll a little smaller than usual to produce the same size sections as in steel. More power will also be required, but heating is not necessary with the chrome-nickels but may, at times, be advisable with straight chromes, depending on the job, section and condition of the metal.

DRAWING

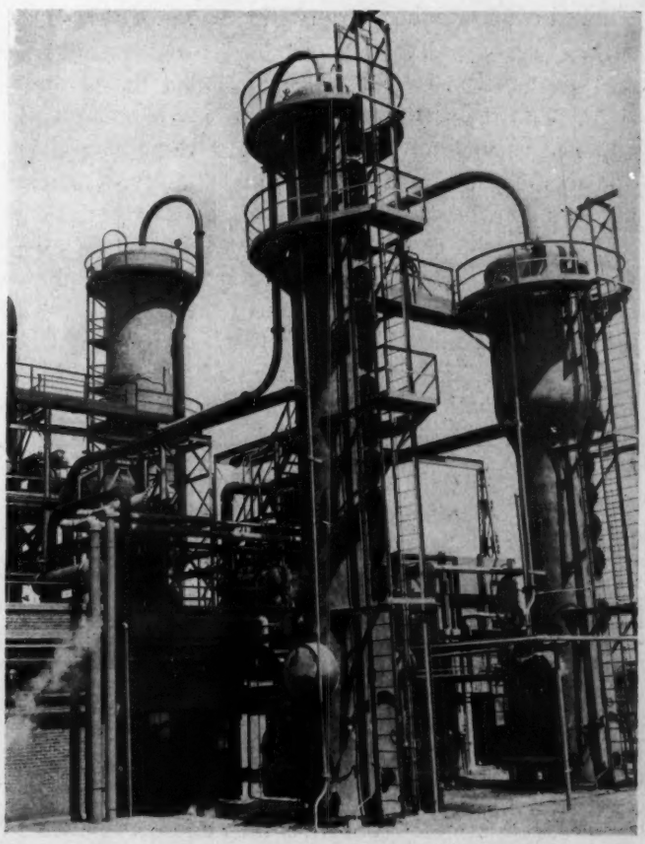
Due to the high ductility of 18-8, very deep draws can be made in one operation. This is a big advantage in cold flanging on a press. Greater clearance should be allowed between the dies than for steel, about two to three times as much. The speed or rate of drawing should also be slower than for steel. Reductions of 40 per cent can be made, but it is advisable to stay below 25 per cent. If the draw is too great, annealing should be done at once as cracking is very apt to develop. With the lower values, this is not a factor. If more than one draw is necessary to obtain the required depth, such as deep cylinders or sleeves, it will be necessary to anneal and pickle between operations to eliminate strains, as the metal hardens rapidly on cold working. If finished work is subject to heating and cooling, it should be annealed before going into service. Two light operations can frequently be produced without an anneal, provided the metal has not hardened too much. Any good drawing lubricant with a fairly heavy body, which will not squeeze out under the heavy pressure applied, will give the best results. Frequently, soap solutions as ordinarily used on steel, have been found entirely satisfactory, especially if some scratching or scoring is not objectionable.

WELDING

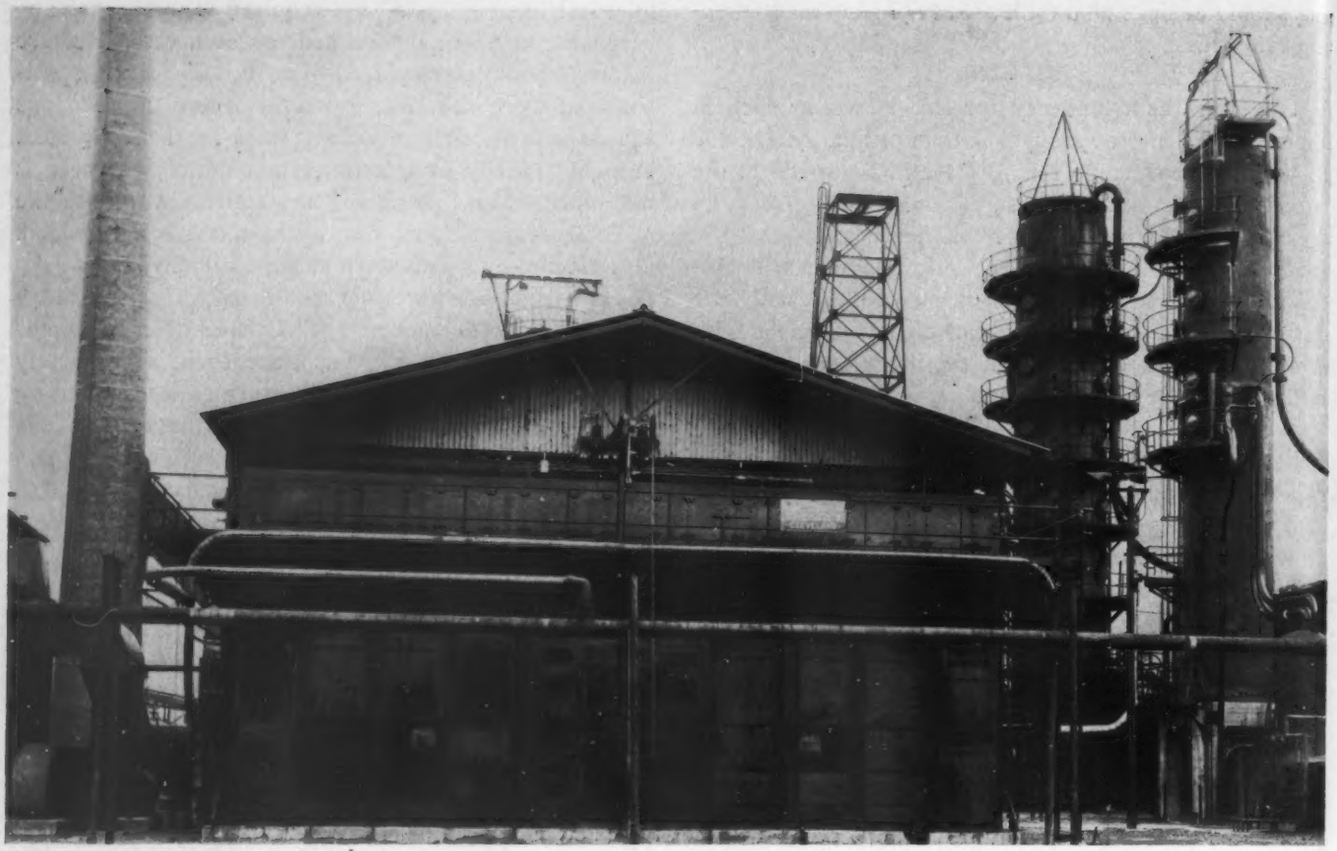
Any commercial method of welding, except fire or hammer welding, will produce good strong ductile joints. Fire welding is unsatisfactory as a refractory oxide film forms on the surface during heating and is insoluble in the commercial fluxes. This prevents the plastic metal from coming together when pressure is applied, hence, prohibiting any adhesion or sticking. Arc welding is probably the most extensively used.

It is necessary to use a flux coated electrode to prevent oxidation or burning of the chromium while melted or going through the arc. This flux should melt along with the rod itself, protect the metal in the arc and form a protective slag coating over the deposited metal until solidified. It should not contain any carbon or carbonaceous matter which will tend to raise the carbon content of the weld metal. 18-8 has about 60 per cent greater coefficient of expansion than mild steel, which may cause considerable warping if not taken into con- may cause considerably warping if not taken into con- also has a lower heat conductivity and melting point than steel, hence less heat is required in welding. This, of course, must be determined for each case. Reverse polarity should be employed—that is, the electrode positive and work negative, especially where thin sections are concerned. Where heavy plates are being welded, straight polarity is sometimes maintained, as there is not much danger of fusing through. Always use the same analysis welding rod as the metal being welded. Gas welding is satisfactory as far as quality of the deposited metal is concerned, but being slower, is likely to produce more buckling. The flame or ideal conditions should be neutral, but since such is frequently hard to maintain, a slightly reducing or carbonizing condition is advisable. Acetylene feathers about one sixteenth-inch on the end of the inner blue cone will generally be satisfactory. An oxidizing flame will rapidly burn the alloy while too much carbon will give a carbon pick-up which is not desired.

The straight chrome alloys differ widely from the chrome-nickel in the physical properties after welding. In the as-welded condition, they are all hard and brittle and will not stand bending and have very low impact values. The 4-6 per cent chrome and 14 per cent chrome can be toughened sufficiently to withstand severe bending by annealing at 1350°F. but the 18 per cent chrome and 28 per cent chrome cannot be so treated. The expansion of these is about equal to or a little below common steel, which is in their favor. However, while some equipment has been made satisfactorily from these alloys, they are not considered as good for welding as the



Fractionation system operating in conjunction with newer type distillation facilities. Erected by J. P. Devine Manufacturing Company, Inc.



Dubbs reforming plant, 3,000 barrels per day capacity at Oil City, Pennsylvania plant of The Pennzoil Company. Erected by Arthur G. McKee & Company.

chrome-nickels and should always be annealed or stress relieved after welding.

Spot, seam, flash or butt welding is used considerably and produce very good joints, provided the set-up is right. The time, heat, upset and pressure must all be adjusted very closely to accommodate these high alloys, due to their low melting point and fluidity. Ordinary mild steel, when just fused, will be fairly thick or viscous but the chrome and chrome-nickel iron alloys are very fluid and will flow away much like a thin liquid if given the opportunity. Hence, the upset must be applied the instant the proper temperature is reached before any metal flows out, leaving a hole or void in the joint. Automatic control of operation should be provided on all such welding where fine adjustment of each operation can be obtained.

The chrome-nickel alloys containing higher carbon, around .12-.14 per cent when heated to 1000-1500°F., suffer an inter-granular change known as carbide precipitation in which the carbon is thrown out of solid solution into the grain boundaries or carbides. This will slightly reduce the ductility and impact values as well as corrosion resistance under highly corrosive conditions. This, of course, occurs along each weld on cooling and covers an area generally about one fourth to one half-inch wide, about one fourth-inch on each side. It is generally reduced by lowering the carbon to below .07 per cent or by the addition of a so-called stabilizer such as titanium, to the low carbon product. Corrosion produced by such precipitation is frequently referred to as weld decay, although the weld itself is unaffected as this portion is cooling rapidly from a temperature in excess of 1950°F., in fact, the fusing temperature. Annealing will again put all carbides back into solution.

ANNEALING

Like most metals, best results are obtained from these alloys in the annealed state. Annealing is advised on all severely deformed or strained sections, although in many cases where the strains are not so high, annealing is not required. This is a question to be decided for the individual job.

To anneal 18-8, heat the job to 1900-1950°F. and cool rapidly, air cooling if the section is one sixteenth inch or thinner and water quench if heavier, when commercially practical. This treatment will relieve all strains, will not produce grain growth and will leave the metal in the dead soft condition, suitable for service or for further fabricating operations.

Any temperature above 1200°F. will have a softening effect on the straight chromes. For best annealing, heat to 1400-1500°F. and soak followed by a furnace cool. For strain relieving of weld work on the lower chromes, about 1300°F. is usually satisfactory with a good soak and slow cool.

PICKLING

Annealing, while not raising a heavy flaky scale, will produce a blue oxide on the surface which must be removed before further operations, either by sand blasting

or pickling, generally the latter. A solution of 10 per cent sulphuric acid and eight per cent muriatic acid, both by volume, at 150-170°F., will give about the most economical and satisfactory results. About 20 minutes will generally be long enough to loosen the scale and the work should then be removed and dipped in cold water and scrubbed to remove the scum. It will then have a dull gray surface. A dip in 20 per cent nitric acid will whiten this to a great extent.

SUMMARY

The general field of metallurgy has been separated into certain special areas. In the early stages of such separations, there seems but little relation one to another. As the scientific information piles up, it is found that a very close relation exists. The metallurgy of one special product is transferred to another field where, unless proper credit is given, it may be considered new. Generally after a time, the exact relation becomes known.

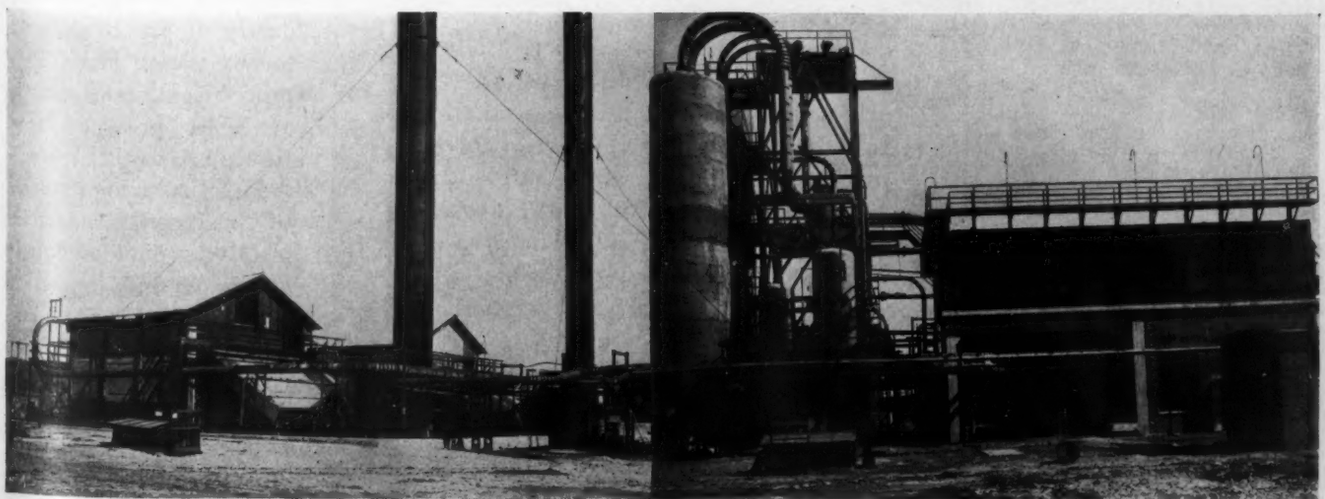
The metallurgy of the special alloys discussed with relation to the oil industry, is now in the middle stage of development. To the steel industry is coming the developments of the brass industry, the electric light industry and the airship industry. The steel industry is very likely to disregard the source of information, in fact, in many cases does not recognize the path by which it arrived. The results obtained by this borrowing process, insure an extremely wide application in not only the oil industry, but in all the temperature-pressure corrosion problems in which metals are useful.

The ability of special combinations of metals to meet certain conditions, is useful. The metallic alloys based upon iron, have an economic advantage that allows them to be applied over a wider field. Those alloys which require a more expensive basic material, will widen their field only by the slow process of economic justification in practical applications.

The iron-chromium alloys with the varied associated elements such as nickel, tungsten, molybdenum and titanium, will be the subject of much study. Many of the products are uneconomic now as for instance, Beryllium in the 18-8 series. It is useful as a guide of probable future developments. This combination of iron, chromium, nickel and beryllium, has been made with the interesting property that it is soft to work and hardens upon heating. This property of hardening upon heating is known in high speed steel and has been the background of the 548 alloy lately developed by Dr. Jeffries. The beryllium alloy should permit stainless construction with very high abrasion resisting qualities. It is fantastic now from a cost standpoint but similar situations existed during the development stage of aluminum, vanadium and other useful metals.

The development in practical way of the X-ray to study structure of these new metallic alloys, has made possible a saving of time. It is to be expected that very rapid progress will be made in the field of alloying. It is reasonable to predict that problems will be presented in the future in which a specific requirement will be met promptly by fitting together the parts of several previous studies. The developments of the last year indicate, for the metallic heat resisting alloys, a future that far overshadows the decorative field from which they were drawn. Their ability to stand up under punishment will justify their application in tonnage that their decorative features could never justify. The entire prime mover energy unit field belongs to them. The whole range of chemical production is open. When one considers the processes akin to cracking such as are encountered in fields other than oil refining, the breadth of application becomes apparent.

These special steels have demonstrated their right to exist. Their ultimate fields will depend more upon the users' grasp of their peculiar qualities so that as tools, they may be used to produce desired results. A certain time is required in acquiring skill with any tool. This time must elapse in the application of these alloys. As many groups apply trial lots and eventually production quantities, the information piles up to aid in additional development. The future of this group of steels is still unknown but bids fair to be the outstanding development of this generation of steel makers.



A modern 25,000 barrel topping plant operating at Grosny, U. S. S. R. Constructed by E. B. Badger & Sons Company

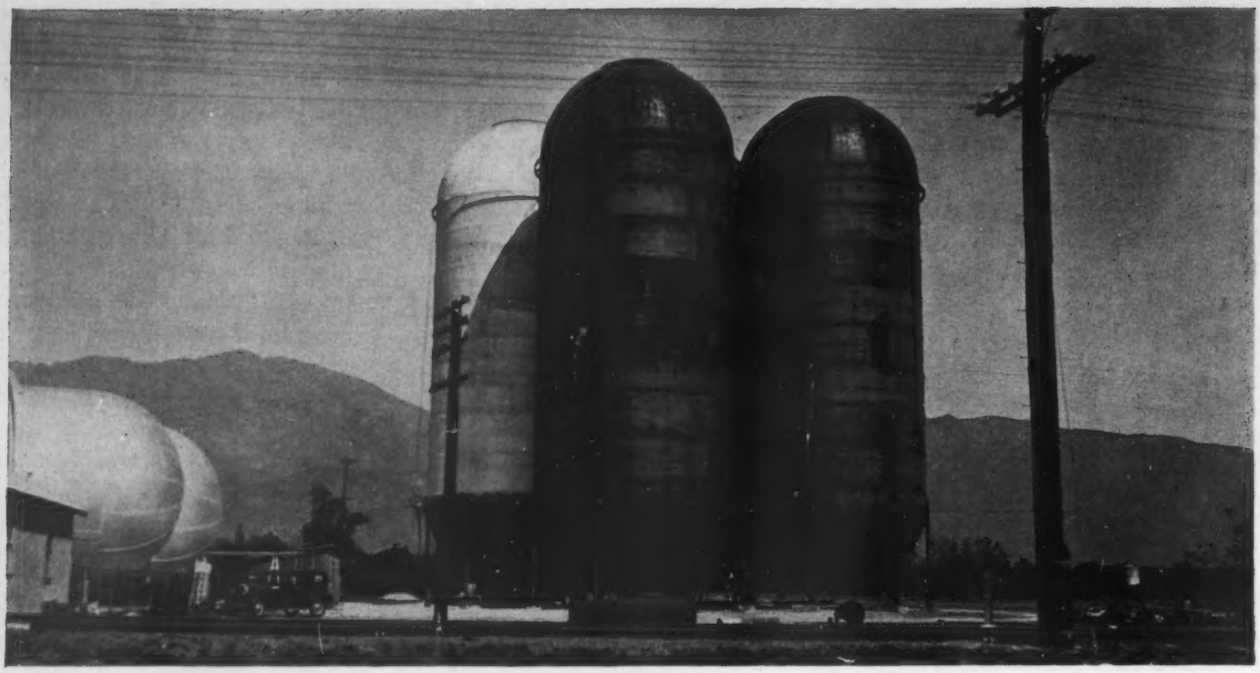


FIGURE 1
Spraying Southern Counties Gas Company (California) gas holders with molten zinc to resist atmospheric corrosion.

Metal Spraying *in the* Petroleum and Natural Gas Industries

H. B. RICE

USE of metal spraying in this industry has developed rapidly during the past year because of the cooperation extended in experimenting with new devices and procedures. This article will cover a few unique and pertinent applications but will not include historical data or a description of devices available. Recent articles have covered the latter fully and industrial engineers are in general familiar with the methods used in the past.

The process is almost as old as oxy-acetylene welding but its development has not kept pace with this welding due primarily to the lack of development of devices to meet the constantly increased demands of modern industry. Improved devices, together with some new procedures recently made available, presage large future use of the process.

Metal spraying consists of melting commercial metals and simultaneously atomizing and impacting the molten particles against surfaces to form continuous, adhesive and cohesive layers of the metal sprayed. Metal in the form of wire is fed automatically into an oxy-acetylene flame and a

IN the accompanying discussion of metal spraying H. B. Rice, Manager, Metal Spray Company, Los Angeles, California, presents new and interesting data concerning the process not included in his paper before the California Natural Gasoline Association, December 8, 1932. The present article discusses many different applications of the process and reports on costs and results secured.

METALLURGICAL SYMPOSIUM

FIGURE 2

Spraying eighth-inch zinc wire on gas holder plate area.

strong air blast atomizes the molten metal and propels it from the nozzle to any surface directed. An air turbine supplies the power to move the wire into the flame and any commercial metal may be used that is available in standard sizes. The nozzle velocity of the molten particles is as high as 50,000 feet per minute, and therefore the devices used are called guns.

All surfaces to be coated must be free from oil or moisture and must be roughened. Blasting with sand or steel grit serves this purpose but often mechanical roughening with air or lathe tools is used in addition. The molten particles impact against the prepared surface at almost the same speed as shot from a shotgun and instantly solidify, forming a mechanical bond adequate for many purposes. Since the molten metal spray is moved over the surface similar to paint spraying, very little heat is transferred to the object sprayed for the reason that one's finger is not burned if passed through a flame rapidly, no heat distortion need occur, and as thick a deposit may be obtained as desired.

One of the largest applications of the process recently performed is that of a natural gas holder of the high pressure type. Figure 1 shows a group of four vertical 250,000 cubic feet holders, one of which is being sprayed with molten zinc on the entire outside area to resist atmospheric corrosion. About 1250 pounds of one-eighth inch and 750 pounds of 12 gauge (.080-inch) zinc was applied to the 10,000 square feet of surface, giving an average thickness of between .004 and .005-inch. Figure 2 illustrates a gun applying one-eighth inch wire to the plate area, and figures 3 and 4 show guns spraying 12 gauge zinc to structural members. Two guns of different types were used and an area of about 400 square feet was sand blasted and sprayed per day. A third type of gun was used while finishing up that sprayed a 50 per cent larger capacity with 12 gauge wire and indicated a substantial reduction in costs if used exclusively. Although all costs have not yet been assembled the average estimate for materials and labor including sand blasting was 20 cents per square foot, or almost twice the cost of painting as previously applied. The user is of the opinion that the cost can be lowered at least 25 per cent on future similar structures because of improved devices and experience gained.

This holder was metal sprayed primarily to establish costs and procedures in order to determine where this process could be economically applied to the several million feet of exposed surface being maintained by this concern. Although an indefinite life is predicted for sprayed zinc or aluminum under such mild corrosive conditions, it is improbable that it will be economical at the location illustrated as paint on the two adjacent horizontal holders at a cost of about 10 cents per square foot is just beginning to fail after being exposed for five years. Even under these conditions it is probable that sprayed metal will serve a good purpose on the calk-welded seams and rivet heads or on specially exposed structural members. At other locations, particularly near the ocean, similar paint lasts less than two years and it is highly probable that such units will be entirely sprayed with zinc, which resists salt air better than

FIGURE 3 **FIGURE 4**

Different types of guns used in spraying 12 gauge zinc wire on structural members supporting gas holder.

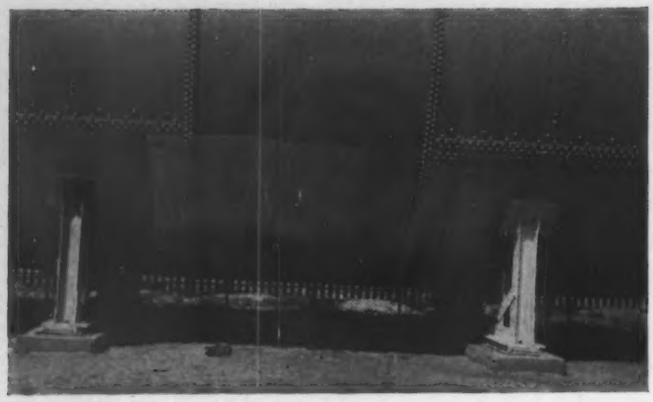


FIGURE 5
Field test conducted by Southern Counties Gas Company, under ocean spray conditions, using sprayed zinc and aluminum.

aluminum. Either metal may be sprayed at about the same cost per unit volume and are sufficiently tight at .005-inch thickness for atmospheric corrosion. However, aluminum sprays cleaner and has a more permanent and uniform color.

Data covering the corrosive resistance of sprayed zinc and aluminum has been available for several years but the information was not deemed sufficient to warrant the expenditure involved in covering such large areas. Therefore, during February of 1932 a field test was designed and applied to a horizontal holder located within 200 feet of the ocean surf where paint required renewal almost every year. As illustrated by Figure 5, an area 10 feet by 10 feet was divided into sections 10 feet by one foot, each section being horizontal and parallel. Aluminum was applied to five sections in thicknesses of from .003-inch to .015-inch, each section having but one specified thickness, and zinc was sprayed similarly on the remaining five sections. One third of this 100 square feet was transversely painted, one third was wire brushed and the remaining one third left with the natural sprayed surface. This gave an excellent field test covering 30 variables. To obtain the effect on angles and corners, two adjacent structural sections of saddles were sprayed with .005-inch of each metal.

Under such atmospheric and ocean spray conditions any openings in the sprayed surface would be clearly evident within one or two days, as iron oxide forms quickly and discloses the smallest pin hole. Monthly inspections have disclosed no evidence of corrosion or failure to date.

Gas and oil burners are subjected to very high temperatures and oxidize rapidly. It has been accepted quite generally that the effects of heat corrosion have been reduced considerably by coating the exposed steel or cast iron parts with aluminum. Some reports claim that the life of parts was extended several times and in all instances where proper workmanship and materials were applied, the additional service obtained has proven economical. Figure 6 illustrates a typical application on two sets of burner parts, a portion of a lot of 74 sets sprayed in a custom spray shop. One eighth-inch diameter aluminum wire was sprayed on the heat exposed portions to a thickness of .008-inch at a contract price of 30 cents per square foot. The actual cost of materials and labor in this instance was 21 cents per square foot. If the sprayed parts are heat treated under certain specifications that cause the aluminum to melt and combine with the iron, forming a surface coating of ferrous-aluminum oxide, a much greater resistance to heat corrosion is obtained.

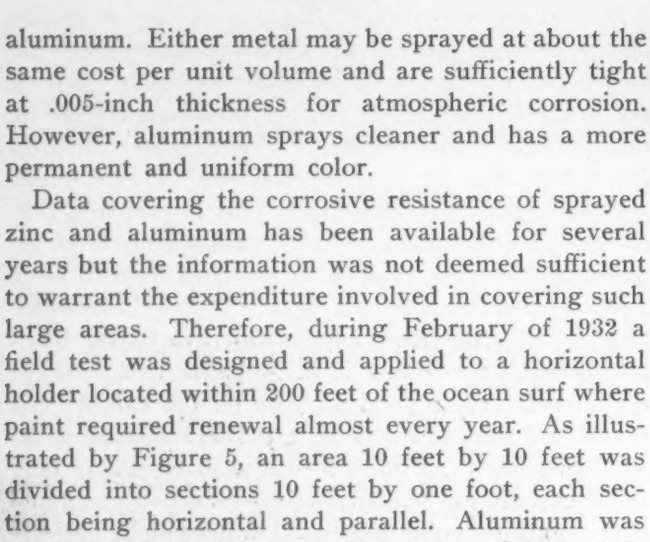


FIGURE 6
Burner parts sprayed with aluminum wire to reduce effects of heat corrosion.

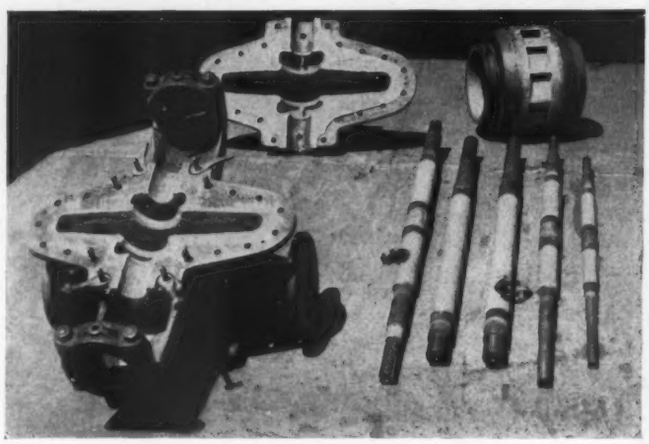


FIGURE 7
Worn and corroded areas on pump parts shown have been replaced by spraying metal on the part. The centrifugal pump parts were sprayed with stainless steel.

Replacement of worn or corroded areas of machine parts with sprayed metal has become quite general practice. Figure 7 shows typical examples. The worn areas on the pump shafts are thread cut or machine roughened, the gun is fastened to the lathe tool rest, and metal is sprayed on the area desired while the shaft is rotated. Any thickness of any metal desired may be applied so uniformly that an allowance of but .01-inch is made for machining to

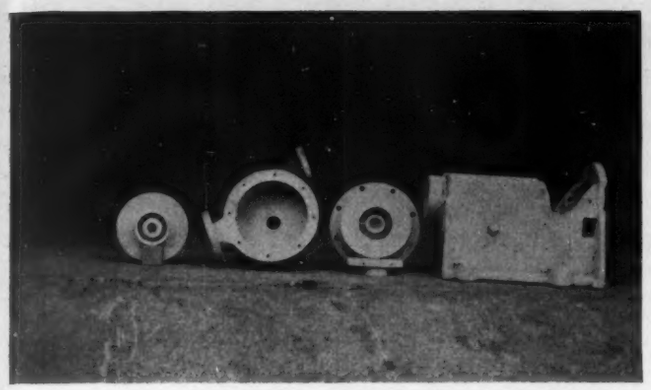


FIGURE 8

Bronze acid pump sprayed with lead—both inside and outside to increase operating life.

size. Heat transfer to the shaft is under full control and need not exceed 200°F. No distortion occurs since the heat is distributed uniformly over the whole circumference. Sprayed metal machines similar to cast iron and is entirely free from hard spots and blow holes.

During the past two years at least 1000 items of machine parts have been observed which were built up to size by spraying one-eighth inch diameter stainless steel, monel, bronze, aluminum, cold rolled steel, Norway iron or high carbon steel. Corrosive resisting metals retain at least 90 per cent of the original resisting qualities. All may be machined with standard lathe tools except high carbon steel which attains about 400 B. hardness and must be emery ground. These items have been watched carefully at all times, have been in service from six months to two years, and in all cases have given service equal or better than the original metals. Included in this list are all forms of centrifugal and reciprocating pump shafts and sleeves, shaft bearings and journals from one inch to 15 inches diameter, cross head pins, valve rods, and internal combustion and compression pistons, cylinders and crank shafts.

Figure 7 also shows a cast iron pump case used for acid oil service. The wear-ring bearings are built up three-sixteenths of an inch, the inside of the case is lined one-sixteenth inch, and the impellors coated one thirty-second inch with stainless steel of 18-8 composition. The refinery has sprayed five similar units that have been in service from six to nine months, and report that there is no evidence of failure or depreciation of the sprayed metal.

Figure 8 is a two-inch discharge, 1750 r.p.m. bronze acid pump used in an acid recovery plant. All machine surfaces were reduced one thirty-second of an inch and all inside and outside areas coated one thirty-second of an inch thick with sprayed lead. The cost of spraying was 10 per cent of the cost of the pump and secured four times the operating life. This application is now standard practice with several refineries.

Figure 9 is a cast iron pump case with a nine-inch open cast iron impellor, used for an acid charcoal solution in the manufacture of iodine from waste water from oil wells. These pumps required major replacements about once monthly prior to metal spraying. One thirty-second inch of monel and lead are sprayed on all interior surfaces at a cost of 35 per cent of the original pump costs, and obtain three times the original operating life. This method has been standard practice in this plant for more than a year.

Figure 10 shows the spraying of lead on a hatch cover of a gasoline tanker. In February, 1932, about 100 square feet of surface on a hatch cover and an upper tank was sprayed with various thicknesses of lead and cadmium. Depreciation of the upper plate structure from corrosion is as high as 50 per cent in six years of gasoline service. The original cost of the plate structure is over $3.00 per square foot. It is believed that sprayed lead will extend the operating life over 50 per cent at a total cost of application of not to exceed 50 cents per square foot. Inspection of this field test on March 23, 1933, disclosed no exceptions. No pealing or porosity was evident while adjacent exposed steel areas showed one-eighth inch of rust and scale.

FIGURE 9

Cast iron pump case and impeller sprayed with monel metal and lead, to handle acid-charcoal solution.

Resistance to hot oil corrosion is always a live subject in gasoline production. Metal spraying is assisting to some extent in the problem and may become a major factor, but the extreme temperatures

FIGURE 10
Spraying lead on a hatch cover on a gasoline tank-ship to retard corrosion.

and pressures involved have required the development of special bonding methods and certain spraying procedures unnecessary in other fields. A number of three-inch and six-inch heavy cast steel valve bodies as illustrated in Figure 11 have been sprayed with stainless steel one thirty-second of an inch thick, and the results have justified continuation of the procedure by this refinery after eight months operation.

A recent article[1] gave the historical date available at that time on the various experiments being conducted on hot oil chambers, and fully described the procedure and inspection results of a re-action chamber operating at 880°F., and pressures of 700 pounds.

Three-sixteenths of an inch pure aluminum wire was sprayed on the entire inside area of 576 square feet at an average thickness of .02-inch. Inspection of 25 per cent of the area after 1500 hours of service showed partial pealing of the coating at one location of about two square feet and was attributed to workmanship.

At this writing there is available the refinery report after 3511 hours of operation, or approximately six months after spraying and placing the unit in continuous service. Twelve per cent of the inside area in various locations was cleaned by scraping off the hard coke and then lightly sand blasting to fully expose the sprayed aluminum. The sprayed surface was blistered in small areas (0.5 to two-inch diameter) covering 10 to 20 per cent of the surface. The underside of the blisters which were removed showed normal spacing and depth of the "key-fasts" made by the bonding tool. The blisters were evenly spaced over the cleaned areas but the hottest end of the chamber showed 25 per cent larger area blistered. Only about five per cent of all blisters were found broken or showed evidence of oil or coke underneath when punctured. One small area in the hottest end, where the aluminum was gone entirely, showed evidence of considerable corrosion and the surrounding aluminum was very thin.

All chambers treated prior to the above were sprayed under contract by experienced job shop operators. This was the first chamber sprayed by this refinery using its own equipment and men. The results are not satisfactory but indicate that 95 per cent protection was obtained for six months at a total cost of $352.10. Improvement in methods and workmanship will probably obtain 100 per cent protection over a six-month period in future applications, or a repair shut-down will permit touching up any weak area. On this basis it is reasonable to conclude that full protection may be obtained on future applications at a cost of less than $1,000 per year. Under present conditions this would prove satisfactory to many cracking unit operators.

The spraying costs and methods described are based on the use of what is known as large diameter wires. Except in one instance all spraying was done with one-eighth-inch or three-sixteenth-inch metal. Although 12 gauge metal may be used economically on jobs shown under Figures 1, 6 and 8, economical features require the use of one-eighth-inch metal in building up shafts, machine parts and large pumps. Also the time element often requires the use of large volume deposits. A re-action chamber may be coated with 200 pounds of one-eighth-inch or three-sixteenth-inch aluminum using one gun in three or four days including bonding. If smaller wire is used, reducing the volume of deposit, either several guns must be employed or the time of repair extended considerably.

As in the early history of welding there is much that is not known in the metal spraying process, but during the past year large strides have been made in devices, bonds and procedures and rapid progress is evident by the many field applications performed and in successful operation, only a few of which space has permitted including in this article.

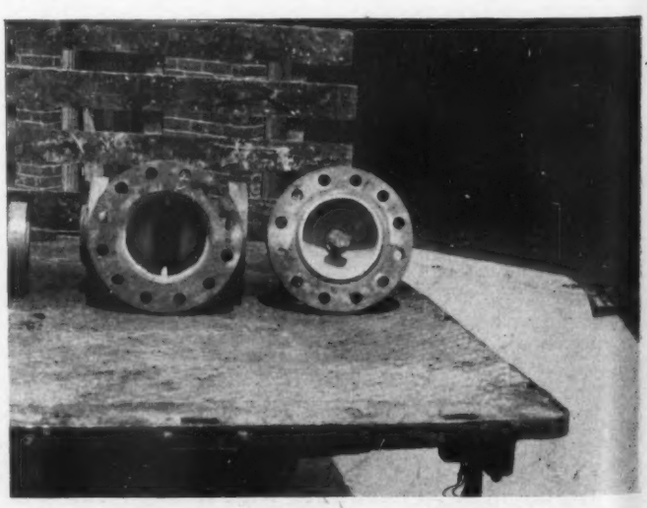


FIGURE 11
Cast Steel Valve Bodies sprayed with stainless steel for service in a large west coast refinery.

[1] "Metal Spraying in Natural Gas and Gasoline Operations," before California Natural Gasoline Association, December 8, 1932.

RAPID METHOD OF . . .

Evaluating Corrosion

CLOYD M. CHAPMAN
Consulting Engineer

THE details of fabrication, methods of utilization and something of comparative results secured through the use of the Chapman Corrosion Tester are presented in this article. This device was developed to provide a simple and convenient means of exposing test specimens to gases or liquids in existing pressure vessels, piping, and the like, while working under pressure or other normal operating conditions, and with minimum interruption of service.

This material is presented through the cooperation of Cloyd M. Chapman, 205 West 39th St., New York City, Consulting Engineer and President of the American Society for Testing Materials.

METALLURGICAL SYMPOSIUM

CORROSION on the interior surfaces of pipe lines and closed vessels presents the difficulty of inaccessibility for convenient observation. To study its progress, either on the vessel itself or by means of test pieces inserted inside, sections of the pipe must be removable or the vessel must be opened for inspection, causing interruption in its normal operations, and usually a more or less laborious and time-consuming operation.

The exposure and examination of test specimens inserted in closed vessels under operating conditions may be greatly facilitated by use of a corrosion tester which provides a simple and convenient means for introducing and removing the specimens at will and without interruption to normal operating conditions.

Such an apparatus is illustrated in Figures 1 and 2. Generally, specimens are attached to the end of a threaded spindle by means of which they are projected through a valve and connection into the vessel for exposure, and withdrawn for inspection by removal of the yoke assembly from the valve. A special one-inch stainless steel hex nipple is screwed into a tapped opening at a point where it is desired to make the tests, and provides connection for a gate valve which remains permanently in place as long as tests are to be conducted at that point. After this connection is made and the valve is in place, there need be no further interruption during the tests to the normal service of the vessel. This is a decided advantage. The particular valve to be used is determined by the conditions, such as pressure and material carried in the vessel, and by its adaptability to the operation of the tester. Normally, the tester is provided with a 200-pound all brass valve for pressures up to that amount, and with a 400-pound Monel

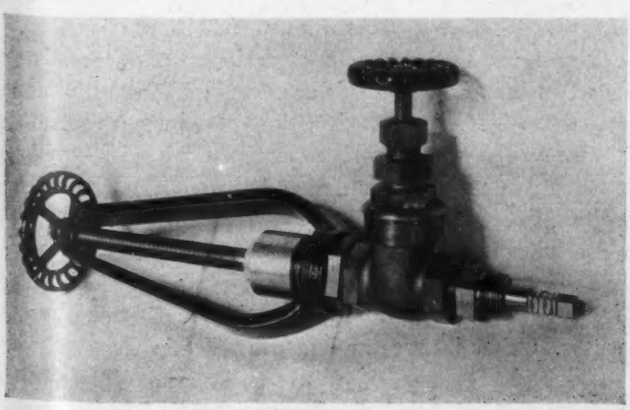


FIGURE 1

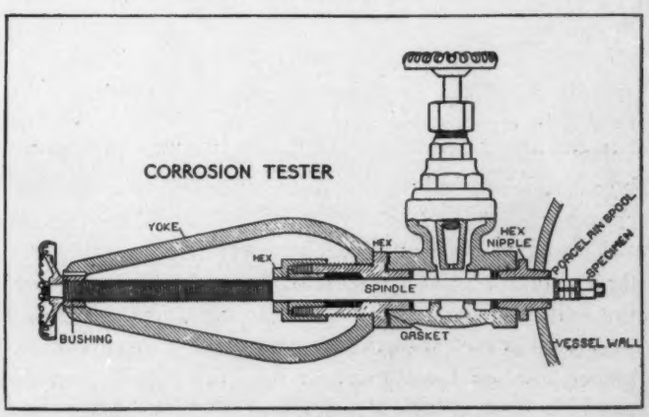
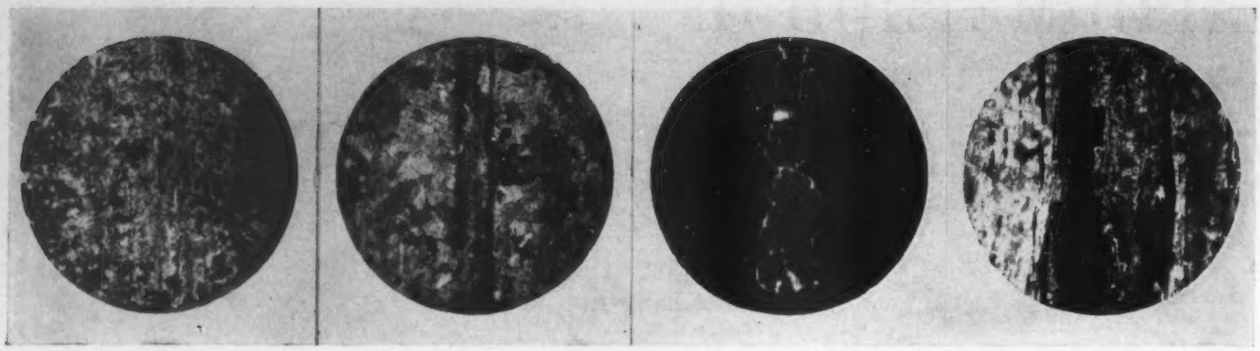
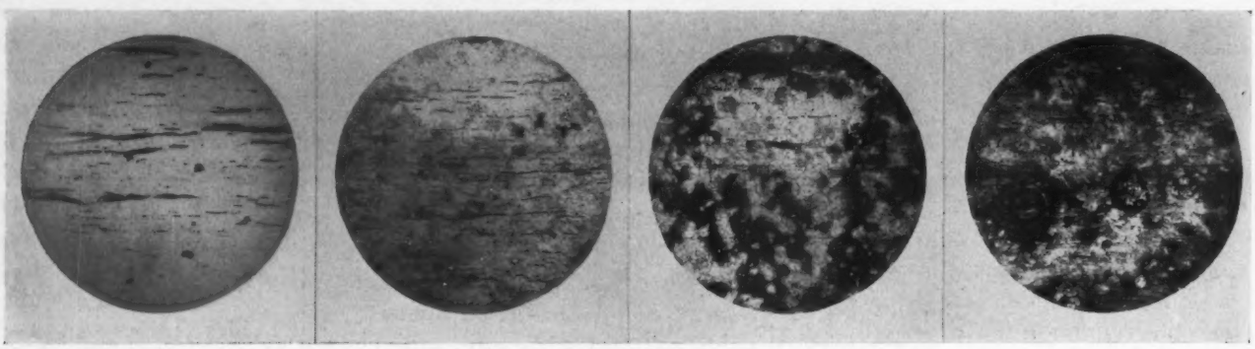


FIGURE 2



A B FIGURE 3 C D

Four specimens, photomicrographed at 50 diameters magnification, different ferrous metals exposed to corrosive conditions in a laboratory test.



A B FIGURE 4 C D

Four specimens of the same materials as shown in Figure 3, and in the same order after exposure to corrosive conditions in river water.

metal valve for pressures above 200 pounds, but valves of other materials and for intermediate pressures may be used if they are available in suitable style.

Attached to the valve is an assembly consisting of yoke, stuffing box and spindle. The stainless steel spindle provides for attachment of the specimens to the end as indicated. The threaded portion of its length works in a bronze bushing in the top of the heat-treated cast aluminum alloy yoke. Double lead threads on the spindle and a large handwheel makes operation easy and quick. The body of the stuffing box is of brass, and is firmly fixed to the yoke. The follower piece is of brass, and the cap of aluminum, with hex head for wrench operation. Square section graphite packing rings are used in the stuffing box.

To inspect the specimens the spindle is first withdrawn as far as it will go. This carries the specimens clear of the valve gate, which is then closed. The spindle assembly, carrying the specimens, is then removed by unscrewing from the valve. That end of the valve is threaded straight to fit the base of the stuffing box and is specially faced for a ring type asbestos filled copper gasket joint.

The exact type and size of specimens to be used is limited only by the diameter of the passageway through the valve and connection (11/16-inch), and to a length which allows clearance with the valve gate, about 1½ inches. A hex head stainless steel tap bolt is provided to carry the specimens on the end of the spindle.

The test method to be used will be determined by the nature of the problem and the preference of the operator. It might be interesting, however, to some readers of this article to learn of a quick method—which has shown promise of considerable usefulness—for determining relative suitability of contemplated metals for resistance to a corrosive element. Essentially this method involves the use of test specimens with one or more exposure surfaces polished to a sufficient degree to permit microscopic detection of the progress and nature of the corrosive attack. It has been shown that a highly polished surface tends to inhibit corrosion, so that the degree of polish given to these specimens is of considerable importance. Experience has shown that for many materials a final finish with No. 4/0 emery polishing paper will not cause inhibition of corrosive attack, and produces a surface readily examined at a magnification of 50 diameters, which is sufficient.

Reference to a problem of selection of materials for heat exchanger tubes subjected to a highly sulphurous hot water—somewhat analagous to refinery problems in the nature of the corrosive element dealt with—will afford an interesting example. Prior to the use of this test, experiments had been carried on for two years with tubes of a wide variety of materials in actual service. This resulted in the selection of a copper-zinc alloy for its high resistance to corrosion in this sulphurous water. Other brasses and ferrous metals followed with various degrees of lessening resistance. On development of the polished specimen method of test, samples from a number of materials tried in the two year serv-

ice test were prepared and subjected to similar conditions.

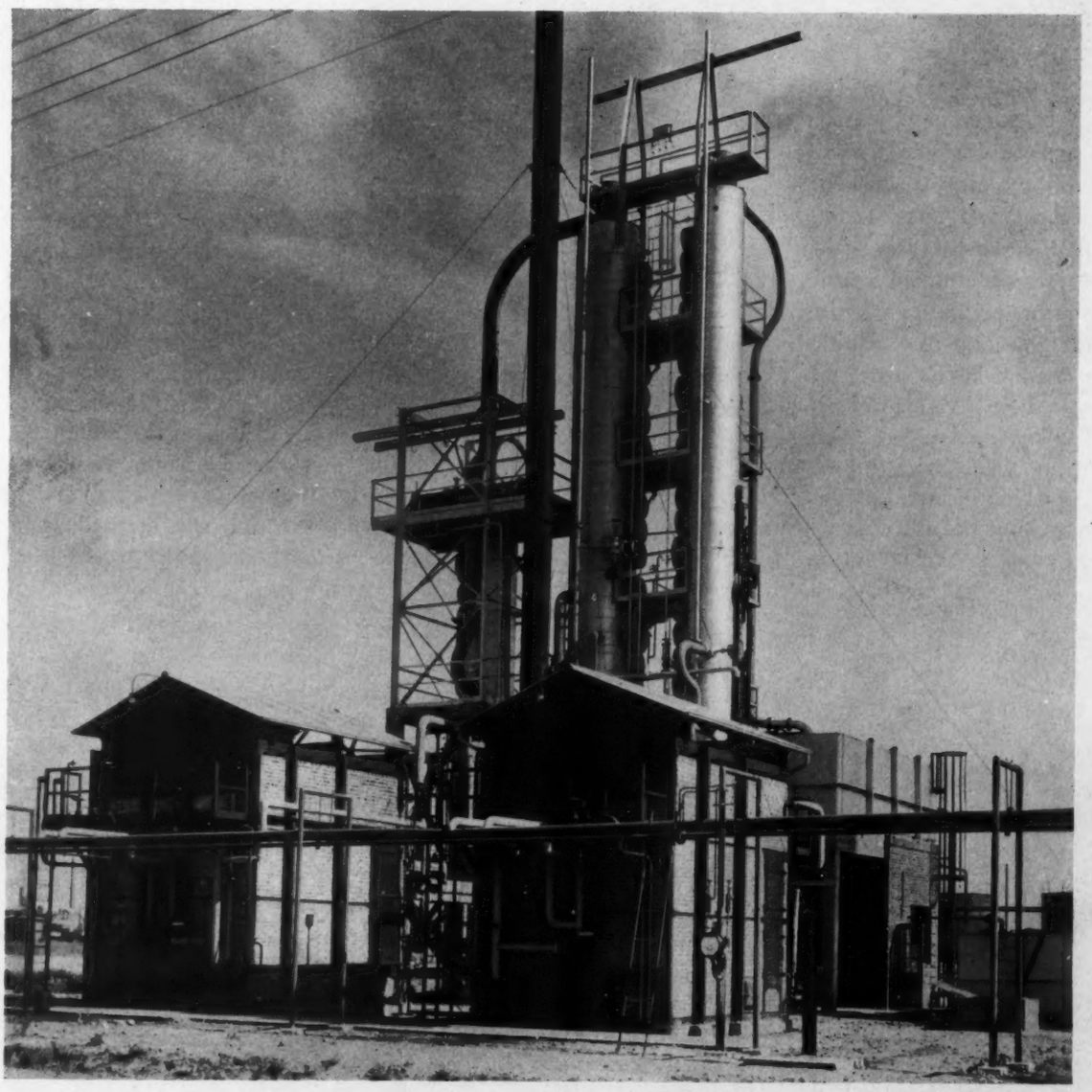
After 16 hours exposure of these polished specimens to the corrosive water they were examined under the microscope and arranged in the order of their apparent resistance by a person not familiar with the results of the two year service test. Two of the brasses, including the copper-zinc alloy selected for service were of the first order of resistance, but did not show a sufficiently distinguishable difference to rate one better than the other; then came a group consisting of a brass and two galvanized ferrous metals which did not reveal a difference, in this time period, sufficient to distinguish a superiority of one over the other; and in the third and least resistant group was a black ferrous metal.

Figures 3 and 4 are introduced to show the nature of results obtained by this method. In Figure 3 are photomicrographs, taken at 50 diameters magnification, of four specimens of different ferrous metals each separately subjected to total immersion for 20 hours at room temperature in 500 cc. of distilled water, to which had been added 2.9 grains per gallon of hydrogen sulphide.

In Figure 4 are photomicrographs of specimens of the same materials (arranged in the same order) immersed under similar conditions in a river water very high in sulphides and containing 0.23 grains per gallon of carbon dioxide.

A very convenient form of test specimen is a one half-inch cube of the metal to be tested, with one fourth-inch hole in the center for attachment to the tester spindle and with edges slightly beveled pass and having one or more of its exposed surfaces polished.

The tester, described herein, is not adapted alone to this form of specimen, nor intended only for the use of polished specimens, but can accommodate other forms and can be utilized for various test purposes and with various methods of test.



Crude charging and redistillation units at Gewerkschaft Elwerath Raffinerie, Misburg, Hannover, Germany, Erected by Arthur G. McKee & Company.

A Lasting Alloy *for* Corrosive Service

WAYNE L. COCKRELL
Metallurgist, Burgess-Parr Company

THE calorimeter bomb familiar in every refinery laboratory sired the development of ILLIUM by Professor S. W. Parr of the University of Illinois. Since that time the alloy has been produced in a large range of casting types such as pump parts, pipe fittings, valves, bolts and nuts and special purpose casting subject to corrosive conditions for which the alloy is satisfactory. In the accompanying article Wayne L. Cockrell interestingly tells of its development, its production, properties and applications.

Metallurgical Symposium

THE advances of the mechanical engineer in the development of labor saving devices during the past 20 years have been paralleled by like advances in the metallurgical art. The metallurgist has constantly provided his mechanical brother with stronger and more lasting materials. The steel maker has made an outstanding improvement in his product by the introduction of substantial proportions of chromium and nickel to render it more resistant to the corrosive action of the atmosphere and certain commonly used corrosive chemicals. These alloys have attained a wide use and in many situations are successfully meeting the requirement for a more lasting material. However, these comparatively low cost alloy steels have their limitation in the matter of corrosion resistance.

In the selection of an alloy for corrosive service many factors may influence the choice. For example, the cost of interruptions in the operation of equipment due to corrosion failure may be the governing factor in the choice of alloy. ILLIUM has found its most useful applications where this factor has been most important and where very long life under severe conditions of corrosion is required.

Even before the introduction of chromium steels for corrosive service there were on the market nickel-chromium alloys with very desirable electrical and heat resistance properties. These alloys possessed some resistance to corrosion and from them the late Professor S. W. Parr of the University of Illinois developed an alloy of greatly improved resistance to chemical corrosives of many kinds. This alloy, known as ILLIUM, has been produced for the past 21 years by the firm with whom the author is connected. It is thought that a brief account of its history and properties may be of interest to oil refinery operators.

A calorimeter bomb for the determination of the calorific value of coal and other fuels provided its

Test bar fracture and bend.

makers a peculiar problem in material selection. The combustion of coal in an atmosphere of oxygen under a pressure of 25 to 30 atmospheres (375 to 450 pounds per square inch) with the production of much heat, more pressure, and some nitric and sulfuric acids, offers a severe type of service. The material for such a bomb must be capable of withstanding these conditions and must be readily machinable and take a good surface finish in order to provide bombs of uniform heat capacity. ILLIUM was developed primarily for this service and the success it has attained in this application is attested by the fact that one of the early bombs in which 50,000 coal determinations have been run is still in use. The calorimeter bombs of Standard Calorimeter Company, and its successor companies have been made of this alloy since 1912.

As the properties exhibited by ILLIUM in this service became known its use spread into other applications so that today it enjoys a wide field of usefulness in handling corrosion problems.

COMPOSITION

The alloy is essentially a nickel-chromium alloy where a portion of the nickel has been replaced with copper to improve machinability, and a portion of the chromium replaced by molybdenum and tungsten to obtain improved resistance to corrosion. There are also present in the alloy small amounts of iron, manganese, silicon, and carbon which are introduced with the other metals or from the materials used to obtain effective deoxidation of the molten metal before pouring. A typical analysis of a production melt is given below.

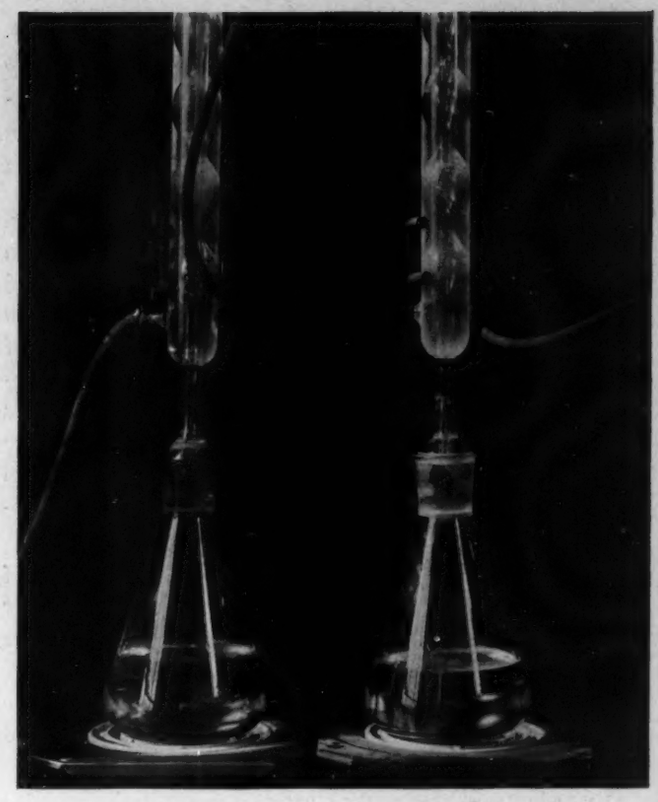
Heat 2-262.

Nickel	58.40%
Chromium	21.80%
Copper	7.95%
Molybdenum	3.52%
Tungsten	2.38%
Manganese	1.72%
Silicon	0.70%
Iron	3.10%
Carbon	0.32%

MELTING

The alloy is produced in the electric arc furnace under carefully controlled conditions and from selected materials to give the composition desired and sound castings of good and uniform quality. The melting procedure has been developed under the careful supervision of trained metallurgists over the entire period of the alloy's production. The quality of metal is subject to constant check by laboratory methods developed by experience. The effects of the constituents whose proportions may vary because of the metals used and the method of melting have been studied. From these studies the necessary checks of composition and quality have been devised to produce uniformity and quality.

It has been found that a proper slag will enable the melter to control oxidation and deoxidation. By means of the slag the tendency of molybdenum and tungsten to vaporize as oxides can be held to a minimum. Losses of metals as oxides entering the slag is prevented by proper deoxidizing conditions in the slag and metal. The slag also enables the melter to control the introduction of excessive amounts of carbon from the furnace electrodes.



Corrosion test apparatus for control of quality.

INSPECTION AND TESTS

Before any heat of the alloy is poured into castings a test bar is cast and fractured. The experienced furnace operator tells from the condition of this casting whether the metal is right and determines what further additions if any are necessary to put it in proper condition to cast. When a satisfactory test fracture is obtained the heat is cast into production items. The inspection continues. Before the castings are approved for shipment or machining operations they are carefully inspected for defects and samples must show a satisfactory corrosion resistance. During machining operations the castings are watched and any defective conditions uncovered are carefully studied and remedies devised before further production of that casting is attempted.

Corrosion tests are conducted on every heat under the direction of a competent chemist. These tests consist of subjecting carefully prepared specimens to the action of boiling sulfuric acid, concentration 25 per cent by weight, for 24 hours. A like determination of the resistance to nitric acid of the same concentration is made at its boiling point. The results of these tests are reported in milligrams per square centimeter of

surface exposed to the acid for the period of the test. Corrosion test results are sometimes reported in inches of penetration per month or year. Such a figure must be obtained from a weight loss per unit of area by a formula similar to that given below:

$$\text{in. penetration/mo.} = 1.419 \times C$$

Where C is the corrosion loss in grams/sq. cm./day. The use of such a figure for reporting the corrosion value is likely to be misleading. It might be assumed from it that one can calculate to the month the time in which a material will last under corrosion. The art of making corrosion tests is not so accurate as this. Laboratory corrosion tests will give satisfactory indications of resistance to a given corrosive and after service data is obtained they are valuable tools in the control of the quality of corrosion resistant material by producers or users of such material.

The standard for satisfactory ILLIUM is a loss of not more than four milligrams per square centimeter per day in either acid and routine tests on a great number of production melts show an average loss in sulfuric acid of strength and at the temperature indicated above of 1.0 milligrams and an average loss in nitric acid under the conditions of testing of 2.0 milligrams.

In order that the quality may be uniform and under careful control, it has been necessary to do considerable work on analytical methods. It is hoped in the near future to publish information regarding these methods in respect to their novel features. The complexity and difficulty of the analytical problem can be realized from the typical analysis given above. These complete analyses are made at regular intervals and such important constituents as chromium, molybdenum, and tungsten are checked more frequently.

CASTING TECHNIQUE

ILLIUM has the high shrinkage of five sixteenths of an inch to the foot and this requires that the foundryman exercise considerable ingenuity in the placing and estimating the size of risers and gates. Experience, the assistance given by the condition of fractured test castings, and X-ray photographs provide the background for this skill in placing risers of proper size. These examinations assure the foundryman of the correctness of his technique.

MACHINING

The alloy is readily machinable compared to many other corrosion resisting alloys. A cobalt high speed steel is satisfactory for machining. The conditions of speed, feed and cut are subject to some variation on account of size and shape and nature of the machine in which the work is done. Surface speeds of 25 to 30 feet per minute with roughing feeds of 0.032 inch are common. In grinding tools a minimum clearance angle is desirable. Lubricants should be used in cutting off, milling and drilling operations. ILLIUM will take a high polish of a steel blue color and the surface is retained without tarnishing effects for long periods in such atmospheres as those occuring

Some of the various types of castings being produced in ILLIUM.

in an analytical laboratory where considerable acid fumes and some chlorine may be liberated.

The mechanical and electrical properties of the alloy are shown in Table I.

Table I—Mechanical and Electrical Properties of ILLIUM

Tensile Strength	60,000 lb./sq. in.	Specific Gravity	8.3
Hardness-Brinell —"B" Rockwell	170-200 87-93	Specific Heat	0.105 cal./°C
Coefficient of Expansion per Deg. C. (20-300°C)	0.0000135	Electrical Resistance	121.9 microhm
Melting Point	1300 C (2375 F)	Machinability—	Comparable with Cast Steel

Figure 1 shows a test bar bent 90° cold in a vise by hammering indicating the ductility obtainable.

There are little service data available on the corrosive conditions encountered in refineries but from experience in other industries where similar types of corrosives are met the following classifications of these conditions are made. Class I includes conditions for which it is certain that the alloy will give good service as shown by laboratory and service tests, Class II includes conditions for which the alloy should be tested before use although experience leads to the belief that satisfactory service will be obtained, Class III includes types of service for which ILLIUM should be tested before adoption as a material for service but results in similar service have not been altogether satisfactory.

TABLE II, CLASSIFICATION OF SERVICE CONDITIONS

I	II	III
Sulfuric Acid	Solutions of chlorides.	Free chlorine, wet.
Hydrogen Sulfide	Solutions of hypochlorites.	
Caustic Soda	Combinations of several corrosives for which the alloy is satisfactory individually.	
Lime		

The corrosion resistant qualities will be effectively presented by test results given in Table III.

TABLE III. CORROSION TESTS OF ILLIUM, SERVICE AND LABORATORY

25% Sulfuric Acid Boiling for 24 hrs. loss average 1.0 mg/sq. cm. (max. 4.0 mg.)

25% Nitric Acid Boiling for 24 hrs. loss average 2.0 mg/sq. cm. (max. 4.0 mg.)

Conc. Sulfuric Acid with 1% to 5% Nitric Acid. Service results satisfactory.

10% to 15% Sulfuric Acid containing Zinc, Sodium, and Ammonium Sulfates and Hydrogen Sulfide. Service results satisfactory. Requirements very rigid.

Hot Sulfur Dioxide gas up to 1800° F. Service satisfactory.

The resistance of ILLIUM is not as satisfactory in wet chlorine atmosphere as in other conditions. Development of a composition more suitable for this condition is under way and some encouraging results have been obtained, which it is hoped may be published in the near future.

ILLIUM has been produced in a large range of casting types such as pump parts, parts for rayon equipment, pipe fittings, valves, bolts and nuts as well as many special purpose castings subject to corrosive conditions for which ILLIUM is satisfactory.

Atmospheric distillation unit erected by Foster Wheeler Corporation in the center of the existing refinery of William Briggs Company, England.

Carbon Dioxide *as Flame Preventor in* Welding

WHEN tanks or towers in service in gasoline plants or refineries develop leaks due to stresses or otherwise, customary practice is to take the damaged unit out of service and place it at a point some distance from the other equipment and steam the interior for several hours until all traces of inflammable hydrocarbons have been driven from the vessel. Only then are the welders permitted to begin the work of repairing the leaks. There have been numerous instances when all the vapors and liquids were thought expelled from the interior of the vessel, but when the torch was applied explosions have occurred which not only damaged the equipment but placed the workmen in a hazardous position.

Technical data has been published in Bureau of Mines pamphlet R. I. 3172 in which the results are shown when inert gases were used in conjunction with air and several of the lower boiling hydrocarbons to determine the limits of flammability of the various mixtures. This bulletin compiled by G. W. Jones and R. E. Kennedy presents some interesting data. Working upon the information presented in the bulletin, H. Ross Campbell of the Carbonic Products Company, Inc., C. C. Reeves of the Air Reduction Sales Company, Ben Beatty and C. C. Forrester of the Forrester Welding Company, have made some interesting experiments with the actual containers on which inflammable hydrocarbons were manufactured and stored by using carbon dioxide as a flame preventer when doing the actual repair work.

As shown by the report of the Bureau of Mines, the upper limits of inflammability when carbon dioxide was present was around 28 per cent. Using more of the inert gas than that shown, the welding was carried out by inserting into the vessels a mixture containing around 40 per cent of carbon dioxide. This extra amount was used to provide a factor of safety well above the inflammable point.

Beginning with small containers, a common oil drum was utilized for one experiment in which natural gasoline was poured, the drum rolled around the yard to thoroughly agitate the contents. The drum was then immediately placed upon one of the ends and a sufficient amount of carbon dioxide was forced into the drum from a cylinder to bring the gas content of the void above the gasoline to 40 per cent. Tests were carried out while the carbon dioxide gas was escaping to determine the amount. When the 40 per cent point had been reached, the welder using an ordinary acetylene torch burned a hole in the head of the drum near the opening from which the gas was escaping. No flame from hydrocarbon vapors was found to occur. Continuing with the drum, the welding point was inserted in the drum and played over the openings but the carbon dioxide which had been placed in the drum prevented the vapors from the natural gasoline from becoming ignited.

Concluding some of the relatively small experiments, Continental Oil Company presented a truck tank for repairs which was used in transporting motor fuel, but while in service developed leaks in seams and at one of the drain connections.

As the leaks in the body of the tank were inaccessible when mounted upon the truck it was removed in order that the welders could have access to the point requiring repairs. As soon as the tank was placed in position, a cylinder of carbon dioxide was placed near it and sufficient piping was connected to the fittings of the cylinder that the carbon dioxide being expelled could be directed into the interior of the container. Sufficient carbon dioxide was expelled from the cylinder to place an air-vapor-carbon dioxide mixture containing 42 per cent of CO_2 in the void above the bottom of the tank. As the CO_2 was being placed in the interior of the truck tank, tests were carried out to determine the content by using a Hayes analizer.

Two places needed repairs, as the seam leaked near the rear and under the side and one at the drain connection at the bottom. The seam leak was repaired by using an acetylene torch and the drain connection was repaired by utilizing an electric welding apparatus. Both were brought into service primarily to demonstrate in this test that flame propagation could not occur when sufficient CO_2 was present in the interior of the vessel.

It has been found advisable when making the repairs that a small amount of carbon dioxide be permitted to flow into the vessel while the work progressed. This procedure is to provide a constant content well above the explosive limits when hydrocarbon vapors or liquids are inside the container or vessel. Tests should be carried out at intervals to determine the amount of CO_2 by running absorption tests with the ordinary equipment at hand.

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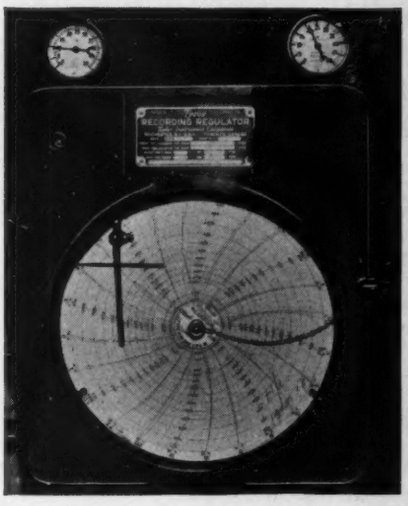

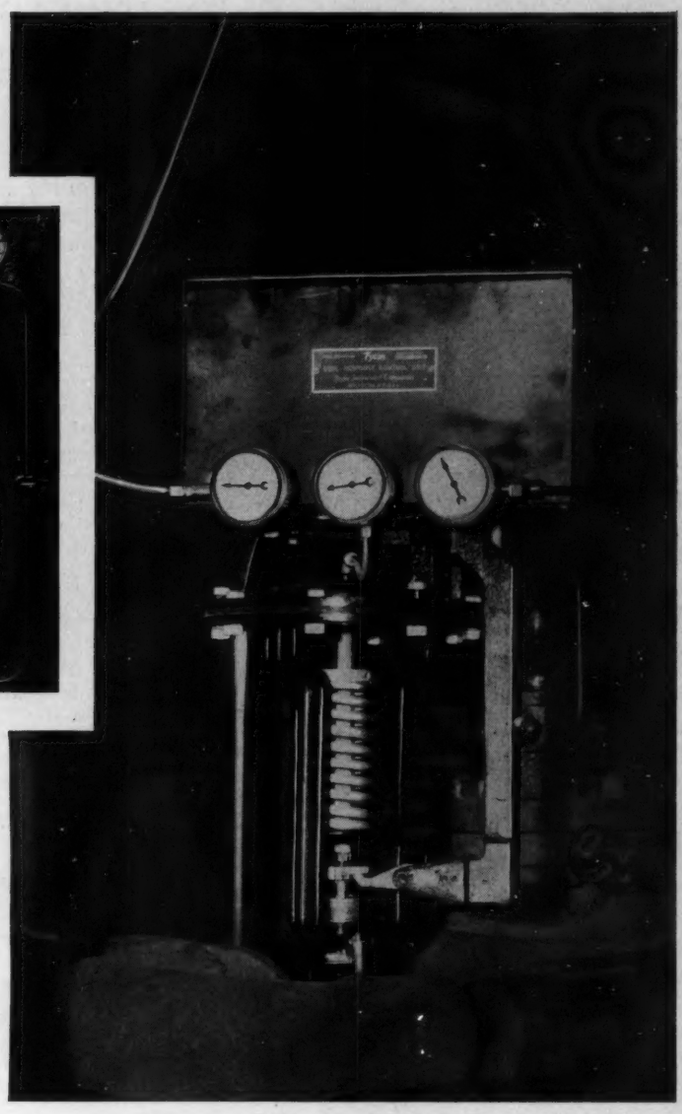

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by

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under the supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstract, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical Data

Total Heats of Gas Oils at Elevated Temperatures and Pressures. W. W. GARY AND L. C. RUBIN. *Ind. Eng. Chem.* **25** (1933) pp. 178-83.

Total heats of four gas oils from Mid-Continent crude were determined in the liquid and vapor states. A continuous flow colorimeter maintained under test pressure was used. The total heats above 32°F. and at atmospheric pressure were found to check the results of Weir and Eaton. Total heats for liquids for virgin gas oils checked the values predicted by the U. S. Bureau of Standards recommended equation for mixed base oils. Total heats of cracked oils differ from those calculated by use of this equation. Comparison of the data determined with those of other investigators shows that an equation for total heats based on temperature and gravity must be restricted in application to stocks or similar characteristics. Equations are presented for virgin and cracked gas oils.

A Method for Interpolating Data, Based on Duhring's Rule. J. H. PERRY AND E. R. SMITH. *Ind. Eng. Chem.* **25** (1933) pp 195-9.

A linear rule for interpolating data, analagous to Duhring's rule and useful for engineering purposes, is described and applied to data on vapor pressure, latent heats of vaporization, electrolytic conductance, specific heats, Joule-Thomson effects, gas solubilities, power factors, and induction periods for the gumming of gasoline.

The Specific Gravity of Fullers Earth. K. YAMAMOTO AND H. IWASAKI. *Report Soc. Applied Chem. Waseda Univ. (Tokyo)* **17** (1932) pp 1-8.

The value of the sp. gr. of Fullers Earth is ordinarily reported as 2.7 to 2.9. However, these investigators found it to be 2.4 for earth dried at 120°C. Alkali treated earth has a higher sp. gr. than acid treated earth. The sp. gr. is changed by heating, is a maximum at 200°C, is somewhat lower at 400°C, and falls rapidly at 600-800°C. The lowering in sp. gr. below 200°C is caused by adsorption of water. The increase above 600-800°C results from structural change in the earth.

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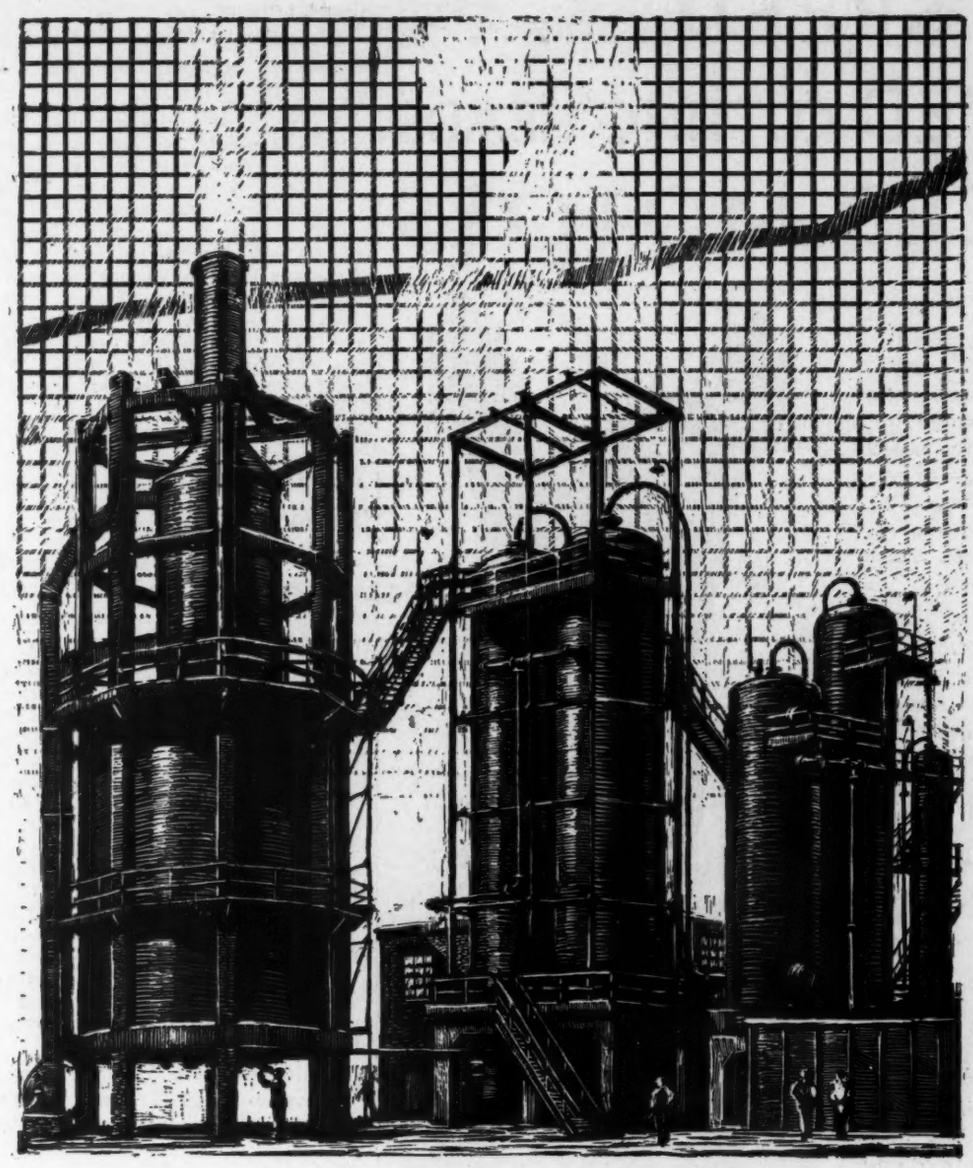
Chemical Composition and Reactions

The Chemical Composition of Petroleum. A. N. SACHANEN. *Gosudarst-vennoe Nauchno-Tekhnicheskoe Izdatelstvo Moscow Petrogard* 1931 pp 344.

Collection of reports from the "Petroleum Research Institute of Grozneft" carried out under the direction of the author. Contains 14 reports, each with a short summary in English.

Terpenes as the Precursors of Petroleum and Its Optically Active Constituents. M. FREUND. *Petroleum Zeit.* **28** (1932) No. 37, pp 1-8.

The optical activity of some petroleums is definite evidence of organic origin. To study the question of the terpenes as precursors, French turpentine, mostly 1-pinene, was polymerized by treatment with anhydrous $AlCl_3$. The resultant product was cracked with and without $AlCl_3$ as a catalyst. The change in optical rotation of the products with rise in b.p. is a du-



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plicate of those occurring in the fractions of natural petroleum.

Structure of Pitch. G. HUGEL AND C. FRANGOPOL. *Ann. des Comb. Liq.* **7** (1932) pp 225-38; pp 417-67.

A new method for studying the structure of pitch is described. This involves the hydrogenation under pressure at 300°C in the presence of alkaline hydrides as catalysts. The product of hydrogenation was refined and fractionated under a vacuum and while passing steam through still. The oil products can be dehydrogenated to give crystalline compounds, such as anthracene, dimethylanthracene, pyrene, etc. The structure of the main components of the pitch is the same as that of components of the oils formed. The conclusion is that the pitches consist largely of polycylic hydrocarbons.

Manufacture: Processes and Plant

The Basic Problems in Connection with the Rectification of Oils. S. N. OBRYADCHIKOV AND A. A. KARASEVA. *Aznefteizdat* 1932 pp 75.

The following items are discussed: (1) The basis of rectification; (2) Determination of the amount of stripped fractions and of the yield of oils; (3) Loss in viscosity during heating; (4) Composition of vapors entering certain section of the bubble tower; (5) Sharpness of fractionation in the rectification of lubricating oil fractions; (6) Hydrocarbon vapor tension diagrams; (7) Diagrams of single evaporation and equilibrium curves; (8) Construction of equilibrium curves for lubricating oil fractions; (9) Heat calculation of towers; (10) Some remarks on the calculation of furnaces; (11) Units for the rectification of lubricating oils; (12) An example of a calculation of a bubble tower for the rectification of lubricating oil. The paper contains 38 figures and diagrams, and 18 tables.

Condensation and Evaporation; New Conceptions and Experiments. M. JAKOB. *Zeit. Ver. Deut. Ing.* **76** (1932) pp 1161-70.

Two forms of condensation are known, the formation of a liquid film at the cooling surface and the formation of drops. High rate of heat transfer favors the latter, as does motionless steam and flow perpendicular to the cooling surface. Film condensation is favored by fast motion parallel to the cooling surface. The driving force of evaporation is superheating of boiling water. This is high next to the heating surface. Hence, steam bubbles grow rapidly close to the wall and less rapidly on rising. Heat transfer to bubbles of steam follows the laws of free convection for small heat loads and those of forced convection for high loads when the rising steam bubbles cause stirring. Numerous references are given.

The Thermol Decomposition of Paraffin Wax in the Presence and in the Absence of Hydrogen of High Pressure. H. I. WATERMAN, A. J. TULLENERS, AND J. DORREN. *Proc. Acad. Sce. Amsterdam* **35** (1932) pp 1063-7.

The high-boiling fractions obtained in high-pressure hydrogenation and in cracking paraffin wax were examined by a new method of study that does not require separation of the individual hydrocarbons. Refractive index, aniline point, bromine number, and mol. wt, were determined. The cyclization occurring in cracking was quantitatively measured, and also the

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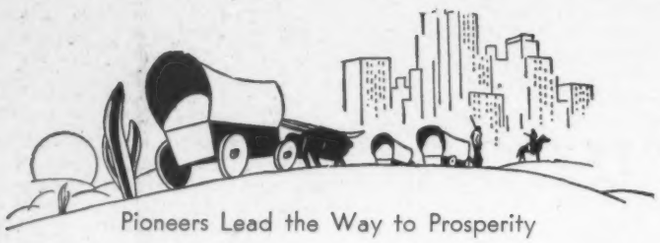

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fact that high pressure hydrogen inhibits cyclization.

Hydrogenation of Petroleum Products. A. SACHANEN AND B. TARASSOR. *Petroleum Zeit.* 28 (1932) No. 46 pp 1-4.

The effect of hydrogenation with and without a catalyst was studied, as well as the effect of pressure, temperature, catalysts, and condition of catalysts. The experiments were made by using the Andreas-Hofer apparatus fitted with stirrer and operated at 200-325°C and 200 atm. for one-half to 3 hours. Hydrogenation of cracked kerosene at high pressure but without catalyst was very slow. Half the olefins were hydrogenated in 3 hours, but aromatics were unaffected. Use of reduced nickel and cobalt increased the reaction velocity ten times. Change of pressure from 50 atm. to 200 atm. increases hydrogenation from 50 per cent to 80 per cent at 300°C. Temperature increase results in increased reaction velocity, but the effect is not as marked as in cracking. The condition of the catalyst is very important. Nickel when made into balls with kaolin was more effective than when applied as nickel powder. A table is given showing the relative value of a number of catalysts. Hydrogenation of heavy distillates, such as paraffin dist. and cylinder oil, is slower than that of kerosene. Molybdenum proved to be a better catalyst for the heavy oils than nickel and cobalt.

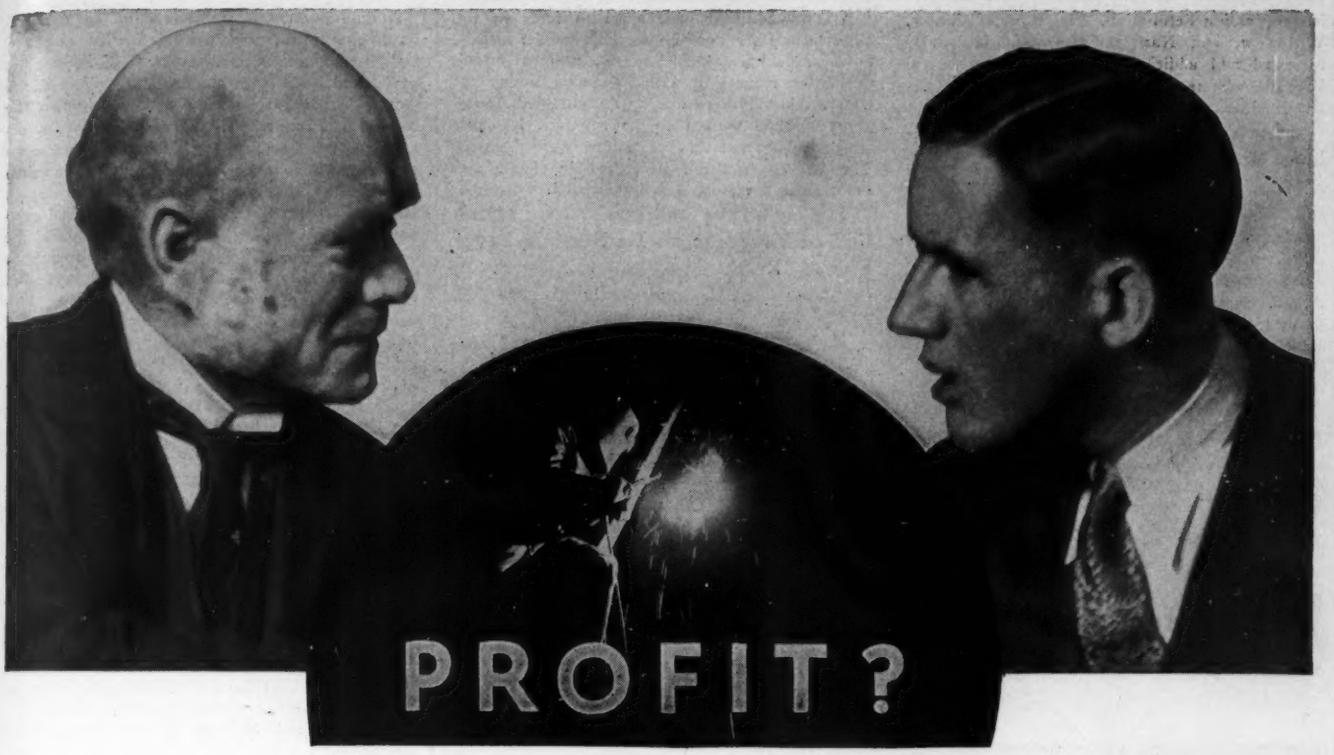
New Methods of Dewaxing and Acid Refining Mineral Oils. N. O. BACKLUND. *Jour. Inst. Pet. Tech.* **19** (1933) pp 1-24.

The use of heavy non-inflammable solvents such as trichlorethylene in centrifugal dewaxing is described. The solution is made in the ratio of 65-45 parts of oil to 35-55 parts of trichlorethylene. The wax phase is lighter than the oil phase and is discharged at the center of the bowl of the machine. The rate of cooling can be more rapid than with petroleum naphtha solutions. The difference between chilling temperature and pour point varies from 0°F. to 40°F., depending on the type of oil dewaxed. The cloud point of the dewaxed oil is found to be within 2-3°F. of the pour point. Refrigeration required is 1/3 to ½ that necesary for dewaxing in naphtha solution. In using trichlorethylene the presence of asphalt in the oil causes no trouble because asphalt is soluble in the trichlor solvent. Hot water is not necessary in the centrifuge bowl when the trichlor solvent is used. The centrifugal separator used will produce 50-100 barrels of oil per 24 hours, depending on the wax content and viscosity of the oil. The process of acid treating described depends on dispersed and equal distribution of the acid, exclusion of air, short time of contact of oil and sludge, and production of oil free from sludge and sludge free from oil. The centrifugal separator used is designed to discharge three components, namely: oil, sludge, and acid. Economy of acid, higher yield of oil, low acidity, smaller consumption of neutralizing reagent, and compactness of plant are among the advantages claimed.

Products: Properties, Utilization and Tests

Work of the Cracked Fuels Committee. F. H. GARNER. *J. I. A. E.* Dec. 1932 pp 40-6.

The article is an appendix to the report of the Empire Fuels Committee and is concerned with the anti-knock properties of typical olefin hydrocarbons that can be present in cracked gasolines. Ethylene was studied in some detail. Amylene, up to 60% concentration in straight-run gasoline, was found to be equal to benzene



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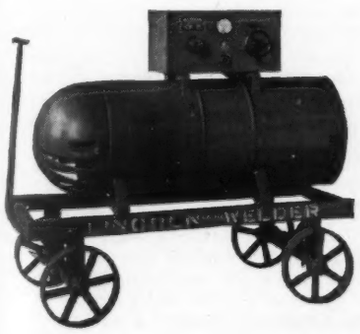

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in suppressing detonation. The work of Garner, Wilkinson, and Nash on the alpha-olefines is reviewed and additional data given on several isomeric olefines. Lead susceptibility was determined in most instances.

Action of Alcoholic Fuels on Aluminum and Aluminum Alloys. O. BAUER AND G. SCHIKORR. *Automobiltechn Zeitschr* **35** 583-9 (1932) 12/25/32.

Alcohol-gasoline and alcohol benzene-gasoline mixtures were brought in contact with pure aluminum, aluminum alloys such as anti-coroda. A. W. 15 and with "pantal." The composition of these metals is given in the table.

Medium	Si	Mn	Mg	Fe	Al
Aluminum (soft)	0.25%	.....	.....	0.29	balance
Anticorodal H	0.90%	0.72%	1.05%	0.30%	balance
A. W. 15 (medium soft)	0.15%	1.65%	.....	0.31%	97.9
Pantal (medium soft)	0.80%	0.64%	0.66%	0.26%	balance

A 20% addition of alcohol to fuels in the absence of H_2O caused no attack on the metals, however 0.15% water showed a uniform attack the latter increasing with increased amount of water. Aluminum treated by the modified Bauer-Voge method proved to be resistant in cases where great amounts of water were present. The experiments are described in detail and the results are plotted and tabulated.

The Influence of Chemical Composition of Kerosene on Its Burning Properties. R. A. VIROBRANZT AND P. A. SENTZOV. *Neftyanoe Khozyaistvo* **22** (1932) pp 331-5; **23** (1932) pp 91-6.

Aniline points, photometric data, sp. grs., refractive indexes, absolute viscosities at 20°C and 50°C, surface tensions at 15°C (dynes/sq. cm.), and pour points were determined for a number of kerosene of Russian origin. The conclusion was reached that it is best to determine the chemical properties of kerosenes by the aniline point method, making determinations before and after mono-hydrate treatment. Illuminating properties depend on chemical composition and boiling range. Viscosity is the determining factor. The paraffin hydrocarbons have the highest original illuminating value but this is lowered in the course of burning. Aromatics have lower original burning value but this increases in the burning process. When uniform illuminating value is desired, 10-20% of aromatics should be present. Naphthenic acids and their salts and sulfur compounds are detrimental and should be removed.

Synthetic Liquid Fuel and Its Importance for the Ural-Kuznetzkii Basin. A. D. PETROV. *Academy of Science of Petrograd* (1932) pp 143.

Covers the subjects of coal liquefaction, low temperature carbonization and cracking of low temperature carbonization tar, synthesis of hydrocarbons from carbon monoxide and hydrogen, condensation of olefines from coke oven plants and cracked gases, cracking of methane, condensation of acetylene, hydrogenation of naphthalene and other components present in tars, synthetic liquid fuel by fermentation and its by-products, combined synthetic hydrocarbon and fermentation plants, properties of mixtures containing benzene, gasoline and alcohol as motor fuels, and, automobiles with gas producers using charcoal.

Effect of Tetraethyl Lead on Octane Number. L. E. HEBL, T. B. RENDAL, AND F. L. GARTON. *Ind. Eng. Chem.* **25** (1933) pp. 187-91.

An empirical analysis was made of the relationship between the concentration of tetraethyl lead and the octane numbers of gasoline to which it is added. A definition was developed for the "lead susceptibility" of any gasoline. The octane number of any gasoline is determined by a combination of five factors incorporated in proper relationship in an ethyl blending chart. This chart can be used for determining the lead susceptibility of any gasoline from the octane numbers of two blends containing different concentrations of tetraethyl lead. Lead susceptibility is not determined by the hydrocarbons alone, but also by traces of other substances present that react with tetraethyl lead. Lead susceptibility of gasolines made from several crudes and by several processes are given.

Detonation in Internal Combustion Engines and the Evaluation of Anti-Knock Properties of Fuels. E. KUZNETZOV *Sgoranie i Detonatziya* (*Combustion and Detonation*) *Aviaavtoizdat* Moscow (1932) 5-23.

Various American and English testing methods are discussed which agree with test carried out with Russian gasolines. It is found that the power of a motor is lowered by detonation, that detonating fuels do not permit a high spark advance, that the degree of detonation depends on the cylinder temperature, I.E. a lower temperature permits the use of fuels with higher detonation. Wet air lowers the detonation while high barometric pressure and high air temperature has a reverse action. Jentsch's inflammability limit testing apparatus is found to be inaccurate when determining ignition points of fuels because of the change in the fuel composition during the experiment. The results of Russian and foreign tests are discussed and 14 literature references are appended.

Characteristics of Oils Used in West-

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GENERAL ELECTRIC

ern Europe. I. A. KUPRYANOV AND N. A. NIKITIN. *Reports of the Lubricating Oil Commission of U.S.S.R.* 1 15-65 (1930).

The properties of oils include the following determinations carried out by the authors with oils procured from various foreign countries; Specific gravity, flash (Martens-Pensky and Brenken), fire, Engler viscosity (at 20°C. and 50°C), pour point, acidity expressed in % SO_3, ash, resins, precipitate after heating, color, electrical break-down test. The types of oils tested were: (1) Light vaseline oils, (2) transformer oils, (3) light spindle oils, (4) heavy spindle oils, (5) light machine oils, (6) medium machine oils, (7) heavy machine oils, (8) extra heavy machine and light cylinder oils, (9) medium cylinder oils (for saturated steam), (10) cylinder oils for superheated steam. The oils tested cover the following countries: Italy, Finland, Scandinavian Countries, South America, Germany, France, Turkey, England, Spain.

What Importance in Practice Has the Dependence of Viscosity Upon Temperature? *Petroleum Zeit* **28** (1932) No. 41, I.P.K. Div. pp 6-8.

Viscosity and oiliness in relationship to fluid and non-fluid lubrication and the relationship between viscosity-temperature factor and the lubrication requirements of an automobile are discussed.

Ozokerite and Paraffin. L. IRANOVSZKY. *Erdol und Teer* **8** (1932) pp 477-8.

The structure of paraffin and ozokerite are discussed. Methods of distinguishing these materials based on solubilities or refractivities are too laborious to be of more than scientific value. The differences in the materials are shown by the behavior of concentrated solutions or pastes. A solvent retention number is determined in a specified manner and is characteristic of the wax material. Retention number is corellated with melting point. The crystallization of the waxes from alcohol solution is characteristic.

Natural Gas; Gasoline and Gas Recovery

Integration and Pulsation Errors in Measurement of Quantities of Gas Flowing Through an Orifice. G. P. MELVILLE. *Jour. Inst. Pet. Tech.* **19** (1932) pp 25-68.

The author discusses the errors involved in the measurement of gas flow in which flow rate and pressure are irregular or pulsating. Considerable errors are involved in the simple integration of orifice meter charts under these conditions of flow. It was found by detailed work in the Singu Field of the Burmah Oil Company that the errors were such that it was impossible to secure a satisfactory balance between gas supplied and gas distributed until the methods described in the paper were applied.

Casing Head and Cracked Gasoline Stabilizing Plants. F. E. TITOVSKII AND V. A. KRUILOV. *Neftyanoe Izdatelstvo* (1932) pp. 128.

The following items are discussed: (1) Preparation of casing head gasoline; (2) Stabilization of casing head gasoline; (3) Rectifying ability of the stabilizer; (4) Efficiency of the stabilizer; (5) Heat constants of the stabilizing unit; (6) Measurements of the apparatus; (7) The basic principles of stabilization and absorption in cracking units; (8) Basic operation methods in stabilizing units; (9) Basic equations for the absorption operations; (10) Purification of gases containing H_2S; (11) The latest developments in stabilization and gasoline recovery from cracked gases.

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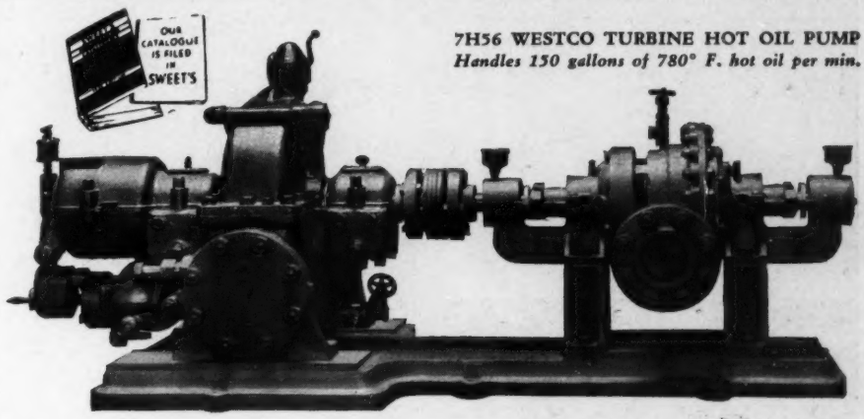

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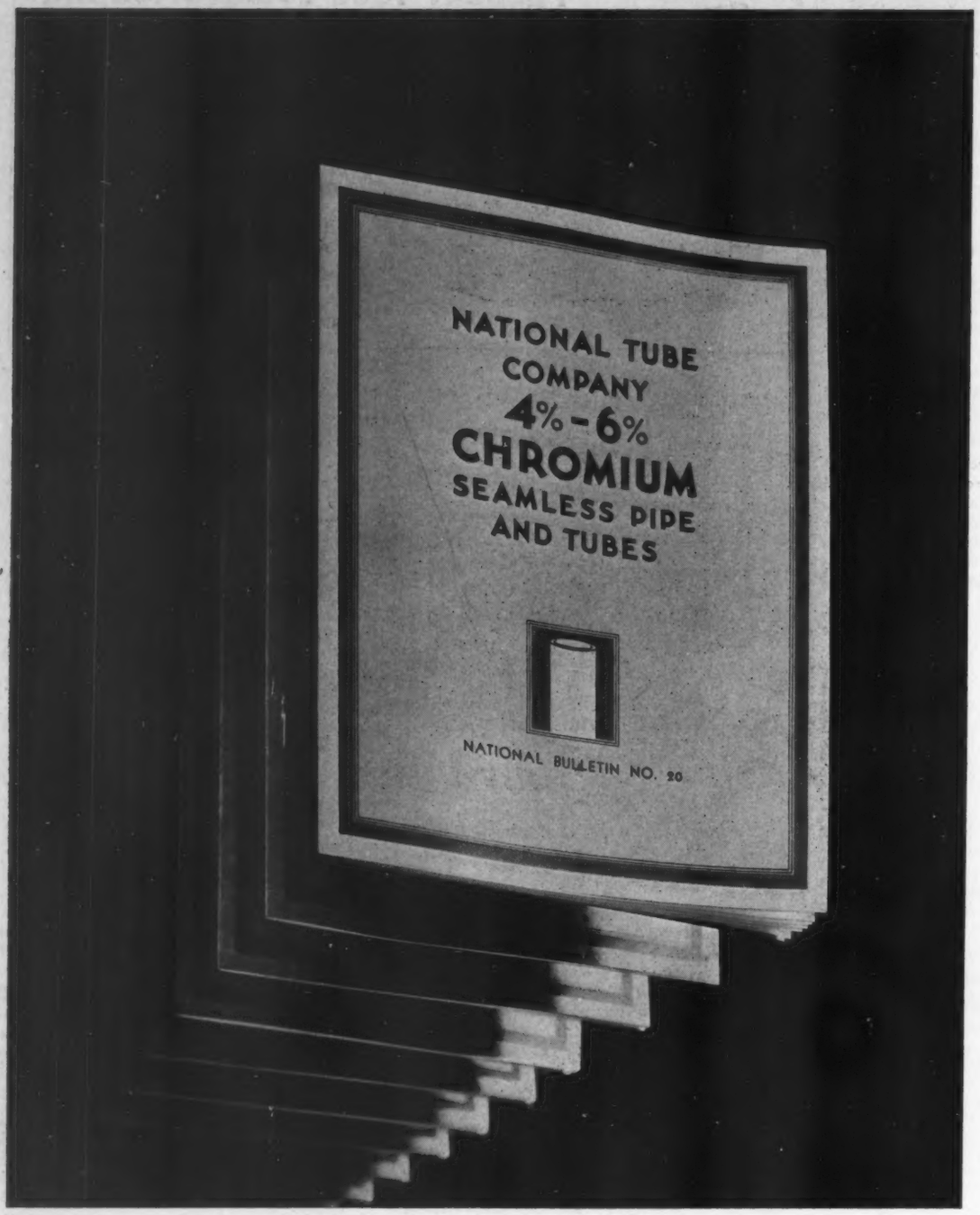

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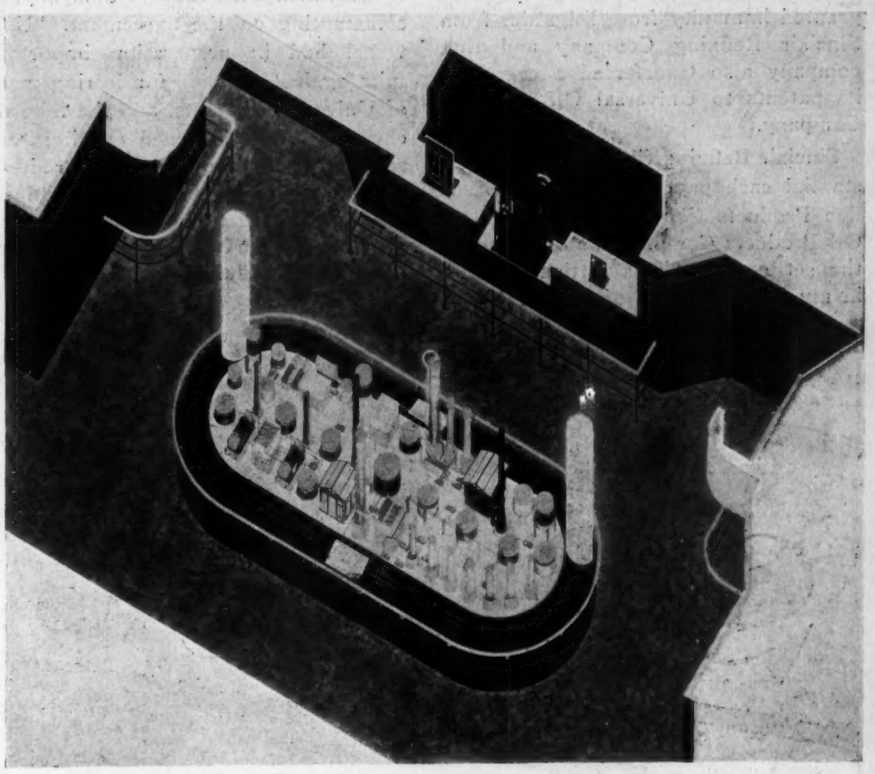
THE MONTH IN REVIEW

Miniature Refinery at Chicago's World Fair

UNDER the auspices of the American Petroleum Institute, an operating miniature refinery will be exhibited at the Century of Progress, Chicago. The accompanying illustration is an isometric view of the Petroleum Industry's refinery, which will be housed in the Hall of Science at the World's Fair. It is constructed almost entirely of glass so that visitors will be able to watch the various processes as they occur in the production of gasoline and other products from crude oil. It is only relatively a miniature plant, since it is actually 30 feet long and 10 feet wide.

The committee charged with preparing the story on petroleum is composed of L. S. Wescoat, vice president, The Pure Oil Company, who is committee chairman; Dr. R. E. Humphreys, vice president, Standard Oil Company (Indiana); Dr. Max G. Paulus, vice president, Standard Oil Company, (Indiana); E. C. Herthel, assistant vice president, charge of development, Sinclair Refining Company and Theron Wasson, chief geologist, The Pure Oil Company. The exhibit is being prepared under the direction of William B. Plummer, Standard Oil Company, (Indiana) and is being fabricated in the shops of The Century of Progress under the supervision of Dr. Irving E. Muskat.



Isometric view of miniature operating refinery to be located in the Hall of Science, Chicago World's Fair

Cracking Patent Rights Further Established

PATENT RIGHTS in the cracking field have been further established and defined through a settlement recently made between Sinclair Refining Company, Universal Oil Products Company and Gasoline Products Company. Under the new arrangements a series of threatened suits will not be prosecuted.

Under terms of the settlement Gasoline Products Company granted a license to Sinclair Refining Company to operate under patents of that company. Sinclair Refining Company, in turn, granted Gasoline Products Company the right to license its cracking patents and released all present licensees of Gasoline Products Company from threatened infringement suits.

As part of the settlement Universal Oil Products Company granted immunity from patent litigation to Sinclair Refining Company and granted that

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concern a license to operate under Universal Oil Products Company patents at its refineries. Licensees of Universal Oil Products Company were granted immunity from litigation from Sinclair Refining Company and that company also transferred a group of its patents to Universal Oil Products Company.

Sinclair Refining Company made substantial cash payments to both Gasoline Products Company and Universal Oil Products Company, under terms of the settlement. "This settlement will, in my judgement, be of great value to the licensees of Universal Oil Products Company and to the refining industry generally," said H. J. Halle, president of Universal Oil Products Company, in commenting on the agreement. "Universal had in preparation important suits against Sinclair for infringement of Universal's patents, and the Sinclair company had threatened our licensees and the licensees of Gasoline Products Company with numerous suits on its patents. These suits will not now be prosecuted. On the contrary, the entire refining industry will now be in a position to get complete immunities from Universal under the Sinclair patents."

R. J. Dearborn, president of Gasoline Products Company, also issued a statement commenting on the settlement in which he states, "This settlement is in accord with the established policy of Gasoline Products Company, and secures for its licensees broader operating freedom and additional immunities without increase in royalties. All of the licensees will be largely benefited by the settlement, and new licenses hereafter granted will include a license or immunity under the Sinclair patents."

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Committee Acts on Several Petroleum Standards

AT the meeting of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants, March 8, New York, in conjunction with the A.S.T.M. Spring Group Meetings of Committees, several actions affecting standards and tentative standards were approved. This committee sponsored the technical program for the Regional Meeting which consisted of a Symposium on Motor Lubricants in which the Metropolitan Section of the Society of Automotive Engineers cooperated.

The following tentative methods of test were recommended for adoption as standard:

Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91—30 T),

Tentative Method of Test for Distillation of Crude Petroleum (D 285—30 T),

Tentative Method of Test for Dillution of Crankcase Oils (D 322—30 T),

Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287—32 T),

Tentative Methods of Sampling Petroleum and Petroleum Products (D 270—30 T).

Minor revisions have been proposed in the latter two specifications listed above. It is the intention of the committee to include these revisions when the test methods are advanced to standard.

Tentative revisions in the following standards are being proposed for advancement to standard:

Methods of Test for Viscosity of Petroleum Products and Lubricants (D 88—30),

Method of Test for Flash and Fire Points by Means of Open Cup (D 92—24),

Method of Test for Cloud and Pour Points (D 97—30).

Action was taken at the meeting to

recommend the revision of the Standard Methods of Test for Sulfur in Petroleum Oils Heavier than Illuminating Oil. These revisions in general affect the accuracy of the test methods. Revisions in the Tentative Methods of Test for Penetration of Greases and Petroleum were also approved.

Technical Committee C on Fuel Oils has been very active and progress was reported on the preparation of specifications for fuel oils. It is expected that proposed specifications will be available for consideration at the June meeting of Committee D-2. In its work, Technical Committee C is giving consideration to the Government specifications for fuel oils.

It was announced at the meeting that at the annual dinner of Committee D-2, Mr. R. E. Wilson, a director of the Standard Oil Company of Indiana, who was recently elected vice president in charge of Research and Development will be the honor guest.

Acting upon the recommendation of A.S.T.M. Committee D-2, the Method of Test for Knock Characteristics of Motor Fuels was approved for publication as a tentative standard by the Committee on Standards.

Temperature Committee Recommends Test Codes

THE Joint ASME-ASTM Research Committee on Effect of Temperature on the Properties of Metals at its meeting, held in conjunction with the Group Meetings of ASTM Committees on March 7 received for consideration two tentative test codes, one covering short-time high temperature tension tests, the other, lone-time high temperature tension tests. Both were reviewed in detail and approved, subject to confirming letter ballot vote, for submission to the sponsor societies.

Progress was made in arranging for cooperation with the Refinery Division of the American Petroleum Institute and the Association of American Steel Manufacturers. A committee was formed subject to approval by the joint committee at its next meeting, to be known as Committee V, Special Committee on Oil Refinery Problems (API and AASM cooperating). Mr. T. D. Tifft of the Sinclair Refining Company was elected secretary of this committee and a start was made outlining some of the initial activities of the group which will be confined to three or four representatives each from the joint committee, the API Refinery Division and the AASM.

Reports of progress were received on the sponsored researches on endurance, creep and structural stability of austinitic nickel-chromium steel at high temperatures under way at the University of Illinois and Battelle Memorial Institute. A report on this work is expected sometime during the year.

Sales of Liquefied Gases Continue Increase

WITH an increase of about 5,000,000 gallons, or a gain of 17 per cent over sales in 1931, the marketed production of liquefied petroleum gases again maintained its annual increase, reaching 33,630,236 gallons. In 1931 sales were 28,769,576 gallons and in 1930 roughly 18,000,000 gallons.

Gases included are propane, butane, pentane and the propane-butane mixtures and the gain record last year was principally in the fields served by butane, especially for gas manufacture. Nearly all of the liquefied petroleum gases marketed last year were produced at natural gasoline plants, with some small production at refineries.

The number of "bottled gas" customers served during the year is estimated at 160,000. Liquefied petroleum gases were being delivered through mains to consumers in 134 communities in 28 states by 55 companies. Shipments of these products by tank car,

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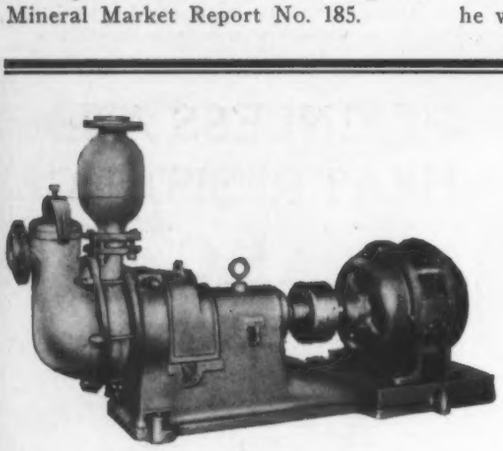
truck and pipe line increased during 1932 by an amount nearly identical with the gain in total sales, while shipments in cylinders and drums showed only a small advance. The 1932 production was reported by 20 companies, five operating in California and 15 east of California. Distribution by California companies totaled 6,173,456 gallons.

A list of producers of liquefied gases may be secured free from the Petroleum Economics Division, U. S. Bureau of Mines, Washington, D. C. A discussion of the industry can be secured by writing the same bureau asking for Mineral Market Report No. 185.

Kirby Establishes Houston Consulting Offices

W. K. KIRBY, petroleum and mechanical engineer, has established consulting offices in Houston at 1812 Petroleum Building. Mr. Kirby has been identified with petroleum recovery and refining activities since 1910 and has been connected with several of the leading engineering and refining companies of this and foreign countries. From September, 1921 to May, 1923, he was professor of petroleum engineering at the Colorado School of Mines. Later he was in charge of the petroleum division of J. G. White Engineering Corporation, New York, designing and estimating refineries, pipe lines and natural gasoline plants. Following work at Dallas as manufacturer's agent and consulting engineer, he was consultant for Graver Corporation, Chicago. Recently he was consulting engineer for Lummus Company, in charge of engineering and construction of cracking apparatus installed for Tide Water Oil Company, Bayonne, New Jersey. He is a member of The American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers and the American Petroleum Institute.

W. K. KIRBY



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Duriron Standard Centrifugal Pumps are built in sizes from 2 in. suction and 1½ in. discharge to 10 in. suction and 8 in. discharge. All parts that come in contact with corrosive liquids are of acid-resisting Duriron.

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Alcohol Threat Passing

NOW that the Iowa legislature has declined to pass favorably on the proposal to require the addition of alcohol to gasoline it may be that the agitation in its favor will subside in Washington. The Illinois legislature also declined to pass a measure to that effect. These are two of the leading corn states and the proposal grew out of a fantastic scheme to benefit the growers of grain.

Although the alcohol proposal is no worse than many others submitted in legislative halls it is a typical example of what comes about when men are ignorant of the fundamentals of economics. If one industry may benefit, no consideraion is given to other industries that may be damaged. There is even less consideration of the consumer, who will pay higher prices for his merchandise.

PLANT ACTIVITIES

Improvements: Gulf Refining Company, at the Port Arthur refinery is engaged in dismantling a number of old shell type stills, preparatory, it is reported, to engaging in a replacement program.

Expansion: Crown Oil & Refining Company, Houston, according to reports will become part of the Pan-American Petroleum & Transport Company, subsidiary of Standard Oil Company (Indiana) along with American Oil Company, Baltimore. Reports state the Houston plant will be materially enlarged, including several new distillation and cracking units. The parent company will give up plans to erect a refinery on land owned at Texas City.

Refinery: Wilcox Oil & Gas Company, Pampa, Texas, authorized immediate erection of 2500-barrel refinery, two miles northeast of Pampa, on Santa Fe railroad, to replace similar plant destroyed by fire, March 12.

Refinery: Jacksboro Refining Company, Jacksboro, Texas, constructing 250-barrel skimming plant south of town on Rock Island Railroad. O. R. Tautenhaun and Chas. Smith, Wichita Falls, Texas, principal stockholders.

Operating: Wichita Refining Company, Wichita Falls, Texas, began operating 500 barrel skimming plant 2½ miles north of the city late in March. Company organized by Roy I. Carter, V. C. Simpson and Ray M. Meyers. (Refiner, March, 1933, page 41a).

Refinery: Paragon Refining Company, Leuders, Texas, erecting 300-barrel skimming plant to run Shackleford County crude. Freeman-Hampton Oil Corporation, 381 Hamilton Building, Wichita Falls, Texas, principal owner and will supply the oil.

Refinery: Transport Refining Company, Prewitt, New Mexico, again reported building 32-mile pipe line and moving small refinery from Wyoming to run Hospah Dome crude. T. D. Boyce in charge of refinery. (Refiner, August, 1932, page 54a).

Gasoline Plant: Hanlon-Buchanan, Inc., reported planning construction of a natural gasoline plant in the Conroe, Texas, field. Mr. Whorton will be in charge of erection.

Cracking: General Petroleum Corporation, Torrance, California, refinery announced $558,000 expansion program to include additional cracking plant, stabilizing plant, pressure distillate rerun unit, acid treating system and remodeling of existing cracking facilities. This in addition to the company's $450,000 construction program announced earlier this year.

Refinery: Starlight Refining Company, Ballinger, Texas, building 350-barrel refinery on Abilene and Southern Railroad, to operate May 10 and process amber colored 44 gravity crude yielding gasoline, kerosene, bright stock and fuel oil. Geo. A. Sonricker, president and owner.

Purchase: J. S. Cosden, head of a group known as the reorganization committee has purchased at receivers sale the properties of the former Cosden Oil Company, bidding $501,000, and subject to formal approval by federal court. Operates refinery at Big Spring, Texas.

Enlarging: Hayton Refineries, Ltd., which recently took over Petroleum Refineries, Ltd., (Gyro cracking units) at Killinghome, near Hull, England, is enlarging through installation of distilation facilities. Contract, Foster Wheeler Corporation. (Refiner, December, 1932, page 51a).

Resumes: Belgo Petroleum Soc. Anon has acquired Raffineries Nationale de Petroles near Ghent, Belgium, and will resume operations. Plant completed in 1930, never operated, has 1000-barrel Jenkins cracking unit.

Building: Falcon Refining Company, Great Bend, Kansas, headed by Henry Dickason of Denver, and Roy Miller, building 800-barrel skimming plant, planning cracking equipment later. (Refiner, March, 1933 page 40a).

Enlarge: Pan-American Foreign Corporation, Aruba, D. W. I., recently visited by large party of Standard Oil Company of New Jersey officials, is to be further improved and enlarged. (Refiner, Feb., 1933, page 36a).

Grease Plant: White Star Refining Company, Detroit, Michigan, reported planning installation of equipment for grease manufacture.

Coke Ovens: Globe Oil & Refining Company, Lemont, Illinois, refinery, let contract to Brassert-Tidewater Development Corporation, for construction of a battery of Knowles coke ovens, complete with pusher, coke quenching car and coke handling equipment. Construction contract to H. A. Brassert & Company, Chicago.

Coke Ovens: Atlantic Refining Company, Point Breeze, Pa., refinery, planning installation of second battery of six Knowles coking ovens.

Improvements: Sun Oil Company, Philadelphia, plans spending $4,000,000 this year in im-

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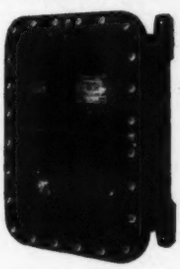
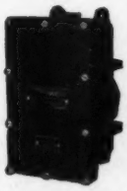
CR7006, Size 1, magnetic switch, 7½ hp., 440 volts, 3 phase



CR7006, Size 2, magnetic switch, 25 hp., 440 volts, 3 phase

CR7006, Size 3, oil-immersed magnetic switch, 50 hp., 440 volts, 3 phase



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CR2941-E1 oil-immersed push-button station

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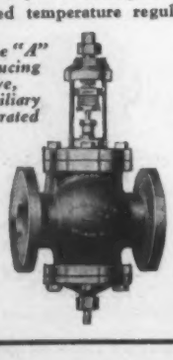

Improving Refineries

proving refineries and other plants, according to company annual statement recently issued by J. Howard Pew, president.

Supplies: National Refining Company through Frank B. Fretter, president, announced it will build up inventories of materials and equipment. Company operates two refineries, service stations in 148 cities in 14 states.

Refinery: Onion Refining Company, Wilson Building, Dallas, Texas, has nearly completed construction of 2000-barrel skimming plant, one mile west Camps Switch, T. & P. railroad, East Texas field. H. J. Strief, general manager of Primrose Refining Company also general manager for Union Refining Company.

Cracking Unit: Gilliland Refining Company, Gladewater, Texas, installing 1000-barrel cracking unit. Operates 1000-barrel skimming plant.

Enlarge: Arrow Producing & Refining Company, at its Overton, East Texas, field refinery, erecting new bubble towers and to enlarge capacity to 8000 barrels. Contract to Ampco Engineering Company, Dallas.

Improvements. Continental Oil Company at Wichita Falls plant is rebuilding furnaces and revamping fractionation equipment.

Cracking Unit: W. H. Daugherty & Sons Company is planning erection of a cracking unit at Petrolia, Pennsylvania, refinery.

Refinery: J. Arthur Hull Company, Tulsa, has tentative plans for erection of combination skimming and cracking refinery, 500 barrel capacity, near Windfield, Kansas. Company operates Kansas Gasoline Company with gasoline plant at Windfield and has crude production in the local field.

Cracking: Marathon Oil Company at Fort Worth now building new distillation and cracking equipment, estimated cost $600,000, contract to M. W. Kellogg Company with Nathan H. Jones in charge of construction.

Lease Plant: Panhandle Refining Company, Wichita Falls, Texas, has leased Kings Mill, Gray County, refinery of King Royalty Company (formerly operated by Dixon Creek Oil & Refining Company). Will operate at 2000 barrels daily.

Purchase: Bayshore Realty Company, San Francisco, purchased Terra Bella Refining Company plant, and according to Joseph Greenbach, manager, will install new equipment and start operating.

Receivership: Deep Rock Oil Corporation is operating in receivership under Ed. H. Moore, receiver appointed by District Judge Thurman Hurst, Tulsa. 10,000-barrel refinery at Cushing, Oklahoma.

Power Plant: Empire Oil & Refining Company, Ponca City plant, installing two 750-horsepower Babcock & Wilcox 250-pound boilers, replacing smaller equipment.

Receivership: Grayburg Oil Company, San Antonio, operating under receivership with Frank E. Kistler, Tulsa, and Ernest L. Kistler, San Antonio, appointed receivers by Federal Judge Duval West.

Stabilizers: Sun Oil Company, Toledo and Marcus Hook refineries will install complete new stabilizing systems designed for the production of liquefied petroleum gases.

Refinery: Crow Oil Company, Ltd., Weyburn, Saskatchewan, Canada, building 300-barrel skimming plant.

Refinery: Big Sandy Oil & Refining Company, proposes erecting 2500-barrel refinery at Gladewater, East Texas field.

Refinery: Blake-Bradley & Stork, building 750-barrel skimming plant at Gladewater, East Texas field.

Refinery: East Side Refining Company building 200-barrel skimming plant near Kilgore, East Texas field.

Refinery: Foshee Refining Company building 750-barrel skimming plant at Gladewater, East Texas field.

Refinery: Roger Lacy, Longview, Texas, proposes construction of 1000-barrel skimming plant at Kilgore, East Texas field.

Refinery: Pacific Oil & Refining Company, Gladewater, East Texas field, building a 300-barrel skimming plant.

Refinery: Pan-American Refining Company building 500-barrel skimming plant at Kilgore, East Texas field.

Refinery: Patty Oil Company building a 250-barrel skimming plant near Gladewater, East Texas field.

Refinery: Stano-Tex Refining Company building a 300-barrel skimming plant at Kilgore, East Texas field.

Refinery: Marion Travis and C. Kroll erecting a 500-barrel skimming plant at Kilgore, East Texas field.

Refinery: Tyler Refining Company, Tyler, Texas, building a 1000-barrel skimming plant at Arp, East Texas field.

Refinery: Union Refining Company, Dallas, building a 2000-barrel skimming plant at Camps Switch, East Texas field.

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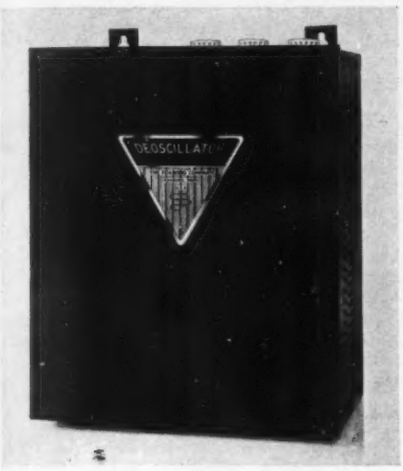
New Equipment for the Modern Plant

1. Deoscillator

THE FOXBORO COMPANY

The Foxboro Company, Foxboro, Massachusetts, announced the Deoscillator with which anticipatory control action may be obtained with any pyrometer controller. This anticipating action improves control operation by eliminating "hunting" or over-controlling.



Foxboro Deoscillator

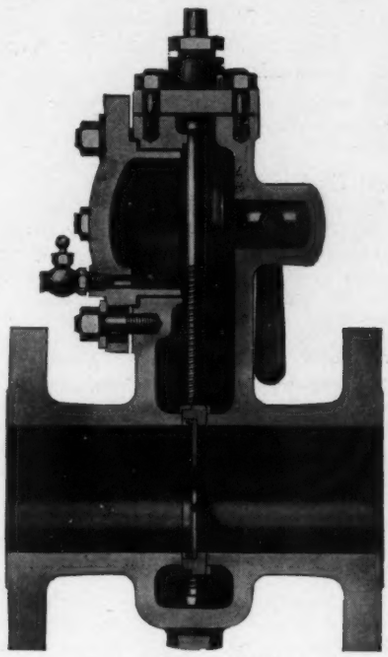
The Deoscillator is "cut-in" between the thermocouple and the controller. In operation, the instrument impresses into the thermocouple circuit a slight additional E. M. F. that augments the thermocople E. M. F. when the temperature is low and opposes it when the temperature is high. This causes the controller to close either the high or low circuit a little ahead of the actual temperature demand. The anticipatory effect prevents excessive overrun or underrun of the desired temperature.

2. Orifice Fitting

SOUTHWEST WELDING & MANUFACTURING COMPANY

Southwest Welding & Manufacturing Company, Alhambra, California, has recently introduced a new fitting which embodies improvements in orifice design. Because of its extreme compactness, light weight yet sturdy construction, this fitting, known as the Lucas orifice fitting, adapts itself to any installation.

According to the manufacturer, it offers three advantages. The necessity of head room for an elevator screw or for disc removal has been eliminated. With it is also eliminated the likelihood of



Lucas Orifice Fitting

damage occuring when the orifice plate is removed at top of a fitting. The elevator stem no longer screws out of the top plate, but remains in position similar to a non-rising stem gate valve.

The orifice is centered in the fitting, as well as being concentric with the axis of the pipe, and is locked during operation. This feature permits the flow of gas or liquid to come from either direction, and the installation of the fitting may be made at any angle desired.

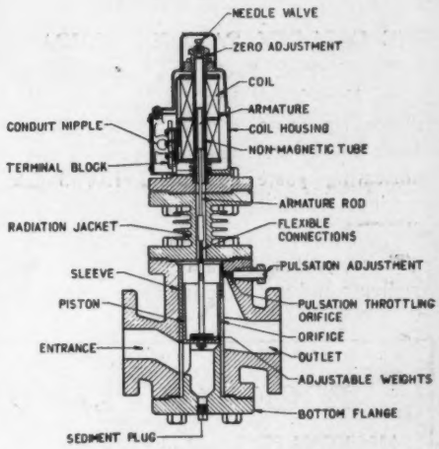
Another feature of the Lucas fitting lies in its elliptical design, doing away with the necessity of rib reenforcing and lightening the various sizes of Lucas orifice fittings from 10 per cent to 40 per cent, depending upon the model. The simplicity and compactness of disc removal mechanism and chamber, relieves hazard from plate changing. Throwing a single lever brings a globe type valve disc directly against the plate carrier, in turn sealing it against the machined seat of the body. Line pressure holds the valve closed.

3. Area Flow Meter

BROWN INSTRUMENT COMPANY

The Brown Instrument Company, Philadelphia, Pennsylvania, has developed the area-type flow meter to measure the flow of certain fluids, which in the past has been difficult due to the complex arrangement of piping and seals required between the meter body and pressure taps when using standard differential and orifice-type flow meters.

The meter-body is a complete unit in itself. No valves, seals, nipples, tubing, mercury or separate orifices required.



Brown Area Flow Meter

Large piston area (5 square inches) enables the meter to operate with a low total pressure drop in the line and yet respond to any changes in the flow conditions. Depending upon the application the meter-body is furnished with either a steam jacket or radiation jacket mounted just below the inductance coil. Changes in the rate of flow are

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REFINER AND NATURAL GASOLINE MANUFACTURER,
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transmitted to the receiving meter electrically thereby making it possible to locate the indicating or recording meter at a remote point from the meter body.

For measuring water (or fluids having approximately the same specific gravity) the ranges vary from 0-150 gallons per hour minimum to 0-2000 gallons per hour maximum. The meter capacity is less for fluids having a specific gravity less than that of water. It is furnished in one pipe size only, two-inch. Where pipe line is smaller or larger than two-inch, the user inserts a section of two-inch pipe for a distance of 15 pipe diameters on each side of the point in the line where the meter body is to be installed.

The area-type flow meter is a meter of the constant head, variable orifice type used for measuring the flow of fluids. The head, or pressure drop across the orifice is held constant while the size of the orifice opening is varied.

4. Lubricating Pastes

THE GARLOCK PACKING COMPANY

The Garlock Packing Company, Palmyra, New York, has developed Garlock lubricating paste compound No. 2 for steam and water packings and Garlock lubricating paste compound No. 3 for packings working against gasoline and oils.

These pastes contain high grade ingredients and are effective and economical lubricants for Garlock packings. When applied to packings at regular intervals friction is reduced, efficiency obtained, and the life of the packings in service prolonged.

Garlock lubricating pastes are packaged in 12-ounce, 24-ounce, and five-pound cans. They are also furnished in larger special containers of any size.

Heat Exchanger

The Lummus Company, 50 Church St., New York, is distributing a new bulletin descriptive of its new high pressure heat exchanger. The booklet is well illustrated with drawings and sketches showing design features.

Controller

The Foxboro Company, Foxboro, Mass., has ready for distribution Bulletin 184, describing its Rotax electrically operated controller with rotating contacts, a new positive operating type of electric contact controller. Diagrams and photographs showing design and application features are included.

Ventilators

Burt Manufacturing Company, Akron, Ohio, announces availability of a six-page, illustrated folder describing its line of ventilators and air intakes, or louvres.

Firebrick

McLeod & Henry Company, Troy, New York, announces availability of a booklet describing "Steel Mixture Oil" brand fire brick for oil fired furnaces. The booklet also describes other types of fire clay brick, high temperature cements, and plastic refractories.

BOOKS ON PETROLEUM AND REFINING

AMERICAN PETROLEUM REFINING—*H. S. Bell, C.E.*

Revised Edition, (1931), includes all recent developments with late information covering all departments, including vapor phase and liquid phase cracking, production of high anti-knock gasoline, design of modern tube stills, modern distillation and fractionation practices, lubricants manufacture, transportation and storage of oil, refinery sites, etc.

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LUBRICATING GREASES—*E. N. Klemgard.*

Practical and scientific data on the manufacture and use of lubricating greases, chemical analysis of many commercial lubricants, abstracts from important patents, formulas and processes for grease productoin. Contents: Manufacture of Cup Greases, Uses, Tests, Analysis and Patents; Soda Base, Mixed Soda-Lime, Sett, Lead Base and Miscellaneous Greases and Compounded Oils; Mechanical Mixtures and the Trend in Grease Research.

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PETROLEUM FACTS AND FIGURES—(Fourth Edition)—*Public Relations Department, American Petroleum Institute.*

Gives complete information and figures on world production, consumption and utilization of petroleum and its products, state taxation of gasoline, production of oil, transportation, storage, refineries and refining, utilization of motor fuel, oil for heat, fuel oil, gas oil, lubricating oils, asphalt, and other data concerning the petroleum industry throughout the world.

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HYDROGENATION—*Carlton Ellis.*

Covers systematically the scientific work on hydrogenation of organic compounds and exhaustively presents full details of the various industries utilizing hydrogenation. Covers new developments in petroleum refining, hydrogenation of coal, synthetic metranol, aromatic hydrocarbons.

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Items About Manufacturers

Northern Equipment Company Erie, Pennsylvania, announces the following extensions of sales territories:

I. C. DeHaven Engineering Company, 1125-27 Circle Tower, Indianapolis, has been assigned all of northern Indiana with the exception of Porter, Lake, LaPorte, St. Joseph and Elkhart Counties.

Economy Equipment Company, Roosevelt Building, St. Louis, has been assigned all the state of Illinois south of the 40th parallel of latitude.

National Meter Company executive offices have been moved from 299 Broadway, New York, to 4207 First Avenue, Brooklyn, N. Y., where the company's manufacturing plant is located. F. J. Bradley, who was for many years in charge of the company's branch office in Chicago, was recently elected president.

Burrell-Mase Engineering Company, Tulsa, has recently completed a pressure distillate stabilizing unit for Deep Rock Oil Company, at Cushing, Oklahoma, and is now constructing one for Bell Oil & Gas Company, Tulsa.

Neilan Company, Ltd., Los Angeles, California, announces that William T. Mayer, formerly representative in the San Francisco territory, has been transferred to the New York office at 19 Rector Street, where he will assist R. B. Werey, manager. Don Church, formerly with the Neilan factory in Los Angeles, will be transferred to San Francisco.

John H. Barker, 154 Nassau Street, New York, New York, formerly agent for La Bour Company, has resigned his connection with that organization but continues at the above address to handle equipment for chemical and process industries.

The Elliott Company, Jeanette, Pa., announced that F. A. Calmus, Pacific Coast manager for Elliott Company and associates, and his staff, located at 813 Rialto Building, San Francisco, California, will carry a small stock of tube cleaners and parts. A warehouse has been opened in Los Angeles at 1732 East Seventh Street with a complete stock of Liberty and Lagonda cleaners and parts. C. W. Cooper is in charge. Mr. Cooper, formerly with the C. C. Moore and Company Engineers, Inc., is well known to the trade on the Coast.

Neilan Company, Ltd., Los Angeles, California, announces that from now on the line of compensated temperature, pressure, flow and combustion control instruments manufactured and sold by the Mason Regulator Company and the Neilan Company, Ltd., (Division of Mason Regulator Company) will bear the following new trade mark.

MASONEILAN

This new trade mark will be used by both companies on all instruments instead of each company using its individual trade mark as heretofore.

Northern Equipment Company, Erie, Pennsylvania, announces the appointment of The J. W. Murphy Company, as Chicago district representatives for Copes feed water regulators, differential valves, pump governors and allied equipment. The office is located at 431 South Dearborn Street.